

EX LIBRIS

Main Lib. AGRIC. DEPT.

Compliments of
A. M. Ferguson

ELEMENTARY PRINCIPLES OF
AGRICULTURE

“Nature Study is learning those things in nature which are best worth knowing, to the end of doing those things that make life most worth living.”

—Hodge.

Old-time common sense and the close, analytical thought of modern times teach that the elementary school should assist both boys and girls, according to their needs, to fit themselves, practically as well as intellectually, for the work of life.



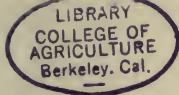
Digitized by the Internet Archive
in 2007 with funding from
Microsoft Corporation



OUR BIRD FRIENDS

What do they eat? See Figs. 119 and 120.

Red Bird or Cardinal (male and female), Bullock's Oriole, Scissor Tailed Fly Catcher, and Meadow Lark.



ELEMENTARY PRINCIPLES OF AGRICULTURE

A TEXT BOOK
FOR THE COMMON SCHOOLS

BY

A. M. FERGUSON, M.Sc.

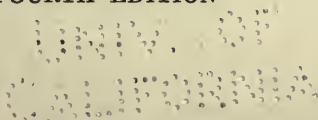
PROPRIETOR FERGUSON'S SEED-BREEDING FARMS

AND

L. L. LEWIS, M.Sc., D.V.M.

PROFESSOR VETERINARY SCIENCE, A. AND M. COLLEGE OF OKLAHOMA

FOURTH EDITION



FERGUSON PUBLISHING COMPANY
CHICAGO, ILLINOIS, AND SHERMAN, TEXAS

5495
F5
1913

COPYRIGHT, JUNE, 1908
COPYRIGHT, May, 1913
By A. M. FERGUSON

First Edition, June, 1908
Second Revised Edition, January, 1909
Reprinted, May and August, 1909
Reprinted, March and September, 1910
Third Revised Edition, April, 1911
Reprinted, October, 1912
Fourth Revised Edition May, 1913

AGRIC. DEPT.

TO THE
AGRICULTURAL

PREFACE TO FOURTH EDITION

It is true that, "Civilization begins and ends with the plow," as we were told by Alexander the Great. It is also true that, the progress of nations (heretofore and hereafter) may be measured by the degree of intelligence that directs the use of their plows. It is no new doctrine that intelligence aids industry. It is, however, a comparatively new application for the schools to aid Agriculture, which is the fundamental support of all civilization. Agriculture is the most backward element in American life to-day, and our schools are meeting a plain duty in correcting the mistakes of the past.

Agriculture is now established as a grammar grade subject, not only as a vocational study for communities that are essentially agricultural, but also as a cultural study for all children who live in a nation whose industries and traditions are so closely related to Agriculture as our own. We study language for its utility in exchanging ideas with our fellows; we study history and civics for guidance in the discharge of our social relations, and likewise other subjects for their usefulness. The new, re-directed spirit of education recognizes that the greatest culture is that knowledge which makes us master of the materials of our environment. We may be scholarly about many things, but uncultured if ignorant of the ideas that belong to our country's greatest industry.

The last twenty years have brought forth many suggestions concerning the scope, the materials, and the spirit that shall enter into the elementary study of Agriculture. The fundamental theory in this text has been to supply

those ideas that will satisfy the natural interest of all children about the *whys* of common farm conditions, and the influence of these conditions on the success of the individual farmer and the nation.

ACKNOWLEDGMENTS

The authors feel a double pleasure in acknowledging the assistance that has made possible the practical school-room success of the earlier editions of this text. To write an elementary text in language that is simple and direct; free from provincial color and accurate without being technical; to satisfy the pupil, the grade teacher, and the supervisor, as well as the practical farmer and a long list of specialists who have a word to say about text books on Agriculture;— for reasonable success in meeting these varied points of view, we owe much to the sympathetic counsel and patient criticism of many trained minds. It is a pleasure to acknowledge valuable assistance from:

Miss Dora Schnell, Miss Ada Henderson, and many other successful primary and grade teachers. On the professional and technical points, valuable suggestions and criticisms have been given by Pres. J. H. Connell of the Oklahoma A. & M. College; Prof. T. V. Munson, an accomplished and distinguished horticulturist, recently deceased; Prof. A. M. TenEyck of the Iowa State College; Prof. V. M. Shoesmith, and Prof. Frank Spragg of the Michigan Agricultural College; Dr. E. S. Tucker of the University of Louisiana; Prof. Wilmon Newell of the A. & M. College of Texas; Prof. Carl Hartman of the University of Texas, and Prof. D. N. Barrow, Editor of *Texas Farmer*.

The following specialists in the United States Depart-

ment of Agriculture have likewise given many valuable suggestions while vising the manuscript: Dr. W. D. Hunter, and Dr. W. D. Pierce of the Bureau of Entomology; Dr. F. J. Cameron, and Prof. Tom Carter of the Bureau of Soils; Prof. C. R. Ball, Prof. S. H. Hastings, Prof. W. H. Long, Prof. C. W. Warburton, and Prof. D. A. Saunders of the Bureau of Plant Industry; to Prof. A. D. McNair for assistance on the chapter on Legumes; and to Dr. David Griffith for the chapter on Pastures, both of the Bureau of Plant Industry, U. S. Department of Agriculture; also to Prof. A. H. Leidigh of the Kansas Agricultural College for the chapter on Sorghums, and to Prof. J. C. Whitten and Dr. W. L. Howard of the Department of Horticulture, University of Missouri, and Prof. J. L. Lloyd of the University of Illinois for assistance on the chapters on Garden and Orchard Crops.

Special acknowledgment is due Prof. J. B. Davidson, of Iowa State College for the chapter on Farm Machinery.

Illustrations have been selected for their accuracy, suggestiveness and educational value. Acknowledgment is due to many officials of the U. S. Department of Agriculture, and to the Kansas Agricultural College for the use of a number of illustrations by Prof. A. M. TenEyck. Other acknowledgments are made in connection with particular illustrations.

TO TEACHERS

In using the text it is recommended that the course extend throughout the session and that the order of the text be followed up to page 117. Suggestions for seasonal projects are given in chapter 35, paragraphs 133, 213a, and in the two last chapters.

TABLE OF CONTENTS

	PAGE
PREFACE	V
AGRICULTURAL LITERATURE	X

PART I

CHAPTER		
I.	Agriculture and Knowledge	1
II.	Plants and Their Food	4
III.	Structure of Seeds	9
IV.	How Seedlings Get Established	12
V.	Plant Substance	24
VI.	How the Plant Increases Its Substance	28
VII.	The Water in Plants	32
VIII.	Structure and Work of Stems.	34
IX.	The Plant as Related to the Soil	40
X.	Soils and Soil Management	52
XI.	Water in the Soil	67
XII.	Relation of the Plant to the Chemical Composition of the Soil	77
XIII.	Improving the Chemical Nature of the Soil	83
XIV.	Productiveness of Soils	95
XV.	Rotation of Crops	100
XVI.	Relations of Plants above Ground	103
XVII.	The Office of Flowers	111
XVIII.	Pruning and Training of Plants	118
XIX.	Propagation of Plants	129
XX.	Improving Plants and Seeds	139
XXI.	Fungus Diseases of Plants	148
XXII.	Insects of the Farm	155
XXIII.	Some Special Injurious Insects	167
XXIV.	Useful Insects	176
XXV.	Wild Birds and Other Insect-eating Animals	180

PART II. ANIMAL HUSBANDRY

CHAPTER	PAGE
XXVI. Animal Husbandry	189
XXVII. Types and Breeds of Cattle	195
XXVIII. Types and Breeds of Horses	204
XXIX. Types and Breeds of Hogs	216
XXX. Types and Breeds of Sheep and Goats	220
XXXI. Farm Poultry	224
XXXII. Nutrition of the Animal Body	235
XXXIII. Farm Dairying	247

PART III. SPECIAL TOPICS

XXXIV. The Home Lot	258
XXXV. School Gardens	264
XXXVI. Forestry	268
XXXVII. Farm Machinery	273
XXXVIII. Public Highways	280

PART IV. CROPS

XXXIX. Selection of Farm Crops	292
XL. Pastures	296
XLI. Legumes.	300
XLII. Grain Crops	305
XLIII. Wheat, Oats, Barley, Rice and Rye	314
XLIV. Corn	318
XLV. Sorghums	330
XLVI. Cotton	335
XLVII. Garden Crops	347
XLVIII. Orchard Crops	356

APPENDIX

A. Books on Agriculture	367
B. Insecticides and Fungicides	368
C. Composition of American Feeding Stuffs	372
D. Per cent of Digestible Nutrients in Stock Feeds	374
E. Nutrients and Fertilizing Constituents in Stock Feeds	375
F. Standard Feeding Rations by Weight	376
G. Standard Feeding Rations per Head	377
H. Annual Rainfall in the United States	378
I. Glossary	379
INDEX	388

TABLE OF CONTENTS

	PAGE
PREFACE	V
AGRICULTURAL LITERATURE	X

PART I

CHAPTER		
I. Agriculture and Knowledge		1
II. Plants and Their Food		4
III. Structure of Seeds		9
IV. How Seedlings Get Established		12
V. Plant Substance		24
VI. How the Plant Increases Its Substance		28
VII. The Water in Plants		32
VIII. Structure and Work of Stems.		34
IX. The Plant as Related to the Soil		40
X. Soils and Soil Management		52
XI. Water in the Soil		67
XII. Relation of the Plant to the Chemical Composition of the Soil		77
XIII. Improving the Chemical Nature of the Soil		83
XIV. Productiveness of Soils		95
XV. Rotation of Crops		100
XVI. Relations of Plants above Ground		103
XVII. The Office of Flowers		111
XVIII. Pruning and Training of Plants		118
XIX. Propagation of Plants		129
XX. Improving Plants and Seeds		139
XXI. Fungus Diseases of Plants		148
XXII. Insects of the Farm		155
XXIII. Some Special Injurious Insects		167
XXIV. Useful Insects		176
XXV. Wild Birds and Other Insect-eating Animals		180

PART II. ANIMAL HUSBANDRY

CHAPTER	PAGE
XXVI. Animal Husbandry	189
XXVII. Types and Breeds of Cattle	195
XXVIII. Types and Breeds of Horses	204
XXIX. Types and Breeds of Hogs	216
XXX. Types and Breeds of Sheep and Goats	220
XXXI. Farm Poultry	224
XXXII. Nutrition of the Animal Body	235
XXXIII. Farm Dairying	247

PART III. SPECIAL TOPICS

XXXIV. The Home Lot	258
XXXV. School Gardens	264
XXXVI. Forestry	268
XXXVII. Farm Machinery	273
XXXVIII. Public Highways	280

PART IV. CROPS

XXXIX. Selection of Farm Crops	292
XL. Pastures	296
XLI. Legumes.	300
XLII. Grain Crops	305
XLIII. Wheat, Oats, Barley, Rice and Rye	314
XLIV. Corn	318
XLV. Sorghums	330
XLVI. Cotton	335
XLVII. Garden Crops	347
XLVIII. Orchard Crops	356

APPENDIX

A. Books on Agriculture	367
B. Insecticides and Fungicides	368
C. Composition of American Feeding Stuffs	372
D. Per cent of Digestible Nutrients in Stock Feeds	374
E. Nutrients and Fertilizing Constituents in Stock Feeds	375
F. Standard Feeding Rations by Weight	376
G. Standard Feeding Rations per Head	377
H. Annual Rainfall in the United States	378
I. Glossary	379
INDEX	388

AGRICULTURAL LITERATURE

Agriculture is older than civilization, yet it is the last large field of human endeavor to develop a literature that is distinctly its own, and the last to find a place in our system of education.

In spite of this comparative newness, our publishing houses now issue books on special and general agriculture that compare favorably with the best in other lines of thought. Every school library should have a number of the more recent special treatises on the important phases of agriculture. A suggestive list is given in Appendix A.

In addition to the volumes published by the regular book trade, the United States Department of Agriculture and the several state agricultural experiment stations publish, for free distribution, bulletins giving accounts of investigations on the varied problems of agricultural science and practice.

Special attention is called to the series of "Farmers' Bulletins," issued by the United States Department of Agriculture, Washington, D. C. They are sent to all parties on request. This series now includes a special bulletin on all the leading field, orchard and garden crops, and the many classes of farm animals. These latter bulletins should be used regularly for supplementary readings in common school agriculture.

Many states have a state department of agriculture that publish bulletins dealing with agriculture. With a few exceptions, all government publications are sent free. Application should be made to the Directors of the state experiment stations.

ELEMENTARY PRINCIPLES OF AGRICULTURE

PART I

CHAPTER I

AGRICULTURE AND KNOWLEDGE

1. Agriculture and Life. "The object of agriculture," says Professor Johnson, "is the production of certain plants and certain animals which are employed to feed, clothe, and otherwise serve the human race." Every American should understand the elementary principles of agriculture, because it is our country's most important industry. Whatever materially affects the productions of the farms and ranches also affects the trades and professions, for the latter are the chief consumers of agricultural products.

2. The Three Phases of Agriculture. There are three phases of agriculture: first, the business phase; second, the arts or crafts phase; and third, the scientific phase. Agriculture, as a means of making a living, is a business. Growing crops and stock, and the manufacturing of these raw materials into finished products, are necessary arts, based on a knowledge of the working of natural forces. The giving of milk by a cow, and the development of a peach from a flower, are natural phenomena. Increasing the flow of milk, and increasing the fruitfulness of a plant, are useful arts. Doing these things

for profit is a matter of business. Knowing how these things are done, how to control the natural forces so that certain results are secured, are matters of knowledge. When all this knowledge is systematically arranged, we have a science. As it is about agriculture, it is agricultural science.

3. Natural Science is organized knowledge of the phenomena of natural objects. The soil, the plants and the animals with which the farmer works are natural objects. A knowledge of the science of the natural objects of the farm serves to guide the farmer in the practice of his craft. Knowing how plants grow is not only interesting, but also useful information to persons who grow plants. The same is true of animals. To know something of how plants grow is to have a knowledge of botany. To know how to grow plants is to have some knowledge of agriculture.

4. A Knowledge of the Science of Agriculture is desirable. Ability to work amounts to little without the application of knowledge. We may know how, or possess the skill to do a certain kind of work, without knowing the reason for doing it in that particular way. A man may guide a team and hold a plow so that it runs smoothly, and yet not know why, or when, or how to plow, to secure a desired result. Hence, we have an art of doing things, and a science of *why*, *when* and *how*. The master workman must possess the scientific knowledge that underlies his trade.

5. How a Knowledge of Agriculture is Gained. Knowledge comes by exact observation and correct thinking. Observations are sometimes incorrect or incomplete. As a basis for correct thinking, we must have accurate observation. Books are merely the printed statements

of what others have observed and thought. Hence, book information is not always in accord with the actual conditions; and, by placing too much confidence in the printed page, one is sometimes misled. An ancient writer stated that a cow had eight upper front teeth. For centuries afterward, this statement was believed and repeated in many books, until one more careful looked into a cow's mouth and found, not eight, but no upper front teeth. Practical farmers, teachers, and books may guide us as to how best to find out, but we must use our own hands, eyes, and minds to acquire knowledge, if we wish to really know. In writing out our observations, we must be careful to distinguish between what is *observed* and the *conclusions* which we make from our observations.

QUESTIONS

1. What is the object of Agriculture? 2. Why should Americans particularly study Agriculture? 3. What are the three phases of Agriculture? Distinguish between these by familiar examples. 4. What is a Natural Science? 5. How does Botany differ from the Science of Agriculture? 6. In what way is a knowledge of the Science of Agriculture desirable? 7. How may this knowledge be gained?

CHAPTER II

PLANTS AND THEIR FOOD

6. Environment is a general term for all the conditions that surround an animal or plant, such as air, soil, water, light, temperature, other plants or animals, etc.

7. Culture seeks to make the environment favorable to the particular plant or animal, or to produce plants and animals better adapted to the environment. The most important conditions are those that affect the supply of the substances used for food by the plant or animal. To encourage the growth of, say, a corn plant, we destroy the weeds that would injure it, and cultivate the ground to make a better home for its roots. To intelligently cultivate plants, we must first learn how plants grow and get their food.

8. Not All Plants Use the Same Kinds of Food. Not all plants are like those familiar to us, as trees, herbs, etc. Possibly we do not often think of the yeast put in the dough to make the bread "rise," or the "green scum" on the ponds, as plants,—yet they are, though very simple ones. The yeast which we get from the grocery store as "compressed yeast" is only a mass of millions of very small plants, each one composed of a tiny mass of living substance, called *protoplasm*.* This mass of protoplasm is surrounded by a delicate membrane, called a cell-wall. These plants are so small that they

**Protoplasm* (meaning primitive substance) is the older term for that part of the cell having the property of life. Some writers prefer the term *bioplasm* (meaning living substance).

can not be seen by the naked eye. When greatly magnified by the microscope, their simple structure is plainly seen. Each plant is only a single cell, such as shown in Fig. 2 *a* and *b*. Each one of these plants, or cells, has the power to form daughter plants, that soon become independent.

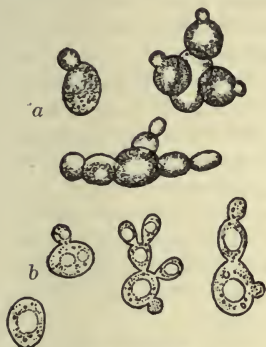


Fig. 2. Yeast Colonies. *a*, surface view of full-grown plants with young branches or buds. *b*, view of similar colonies seen as though cut across. Magnified about 750 times.

9. Fungi. Yeast belongs to a class of plants called fungi (fun-gi—singular, fungus). These fungus plants are very small, but they are very important. The bacteria causing the nodules on peas and clover plants are very beneficial. Some cause disease that destroys other plants, like the rust on oats, mildew on roses and grapes, or the rots of fruits and roots. Other kinds of

these simple plants cause disease in animals, as cholera in swine and chickens. Their food consists of the substances of other plants, or of animals, like starch, sugars, fat, lean meat, white of egg, etc. In order to become familiar with the conditions which favor the growth of yeast-like plants, we shall set up the following experiment:



Fig. 3. Figures of various kinds of Bacteria. After Cohn and Sachs. Very highly magnified.

9a. Food Materials for Yeast. Secure two large bottles or fruit jars, and fill both about two-thirds full of clear well-water. To one jar add a teaspoonful of sugar and about as much of the white of an egg. See that both are completely dissolved. Now add to both jars small lumps of the ordinary "compressed yeast," or dry yeast cake, secured from the bakery. Whichever is used, see that it is well dissolved in a spoonful of water before adding to the jar. Stir well and notice that the liquids are clear, or nearly so. Set aside in a warm place, but not in strong light, and observe once or twice a day for several days. The liquid soon becomes cloudy in the jar to which the food was added, but not in the jar of water. The cloudy effects are due to the large number of yeast plants formed. The sugar and egg substance furnish the nourishment for their growth. They do not multiply in the pure water. Yeast grows in the bread dough because the dough contains all the substances needed for the nourishment of the yeast plants. In the "dry yeast" these tiny cells are in a dormant condition, like seeds.

10. The Green "Pond Scums" belong to a class of plants called algæ (singular, alga). There are many kinds,

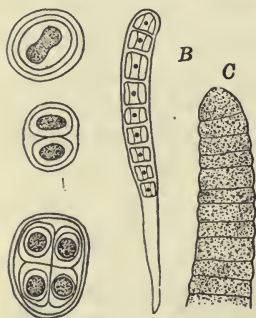


Fig. 4. Cells of Algæ A, a simple one-celled form with the cells embedded in a jelly-like wall. B and C, forms with the cells arranged in chains.

and nearly all of them are very simple, being composed of single cells, or small masses of cells. Algæ contain a green coloring matter, which yeast-like plants do not have. We shall later learn something of the value of this green coloring matter to the plant.

11. The Food Materials of Green Plants are made from water, carbonic acid gas, and the simple minerals dissolved in the natural waters of the soil. These

are combined to make all the substances necessary for the nourishment and growth of their cells. They must

have sunlight before they can make their food materials out of the simple substances named.

11a. Food Materials Used by Green Plants. Use a jar filled with clear spring water, as mentioned in 9a, but add nothing to the jar but a small bit of some common pond scum, secured from the streams or watering troughs. Place the jar in a well-lighted window, preferably a north window. Take care that the water does not get too warm by staying too long in very bright light. Observe from day to day to see if the alga mass is growing larger. It will grow much slower than the yeast plants. The jar may be kept for weeks by adding water from time to time, to make up the loss by evaporation. If the alga grows, we must conclude that it gets all the food it used from the well-water and air, because nothing else was added. The water contains salts dissolved from the soil, and carbonic acid gas dissolved from the air.

12. Green Plants, like the pond scums, herbs, trees, etc., that are able to make their food materials out of simple substances, are called "independent," or "self-feeding plants." Plants like the yeast, which must have their food substances prepared for them, are called "dependent plants."

13. Cellular Structure of Plants. The yeast and algæ are examples of very simple plants. The higher plants which we know as trees, herbs and weeds, are very large, but, if examined with a strong microscope, we find that their bodies are made up of thousands, even millions, of tiny cells, much like the cells of the algæ and

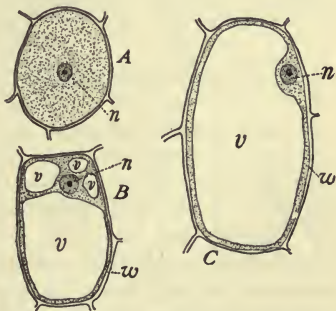


Fig. 5. Growth of individual cells. *A*, a very young cell. *B*, similar cell, but very much larger and older, showing vacuoles or sap spaces. *C*, a still later stage—all greatly magnified. *w*, cell-wall. *n*, nucleus *v*, vacuoles.

yeast, except that their sides are flattened by pressing against each other. New cells are formed by a single cell dividing into two cells (Fig. 6). These new cells grow to a certain size and divide again, and so on till great numbers are formed. (See Fig. 14, C.)

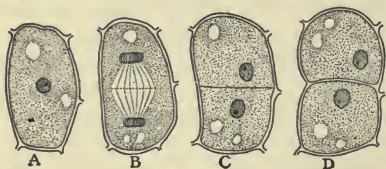


Fig. 6. In forming new cells the living substance or protoplasm divides and then a cell-wall is formed between them.

14. The Living Substance of Cells.

The cell is the unit out of which all plant and animal bodies are made, just as the brick is the unit out of which buildings are

made. Within each cell-wall is the living substance, called protoplasm. It differs from dead substance in that it has a different chemical constitution, and the power of self-action. Protoplasm is a clear granular substance, like the white of an egg or mucilage. It differs from these in that it has *life*.

QUESTIONS

1. Define environment.
2. What is the purpose of "culture?"
3. What is the most important condition of plant environment?
4. Describe the yeast plant.
5. Name other kinds of these simple plants, and mention their importance.
6. What do you learn from the yeast experiment as to the kind of food used by the yeast plants?
7. What is the chief difference between a fungus and an alga?
8. What do you learn from the "pond scum" experiment as to the food of the algæ?
9. Are the higher plants, such as herbs and trees, in any way similar to simple plants, such as yeast and pond scum?
10. Why are green plants called independent; fungi, dependent plants?

CHAPTER III

STRUCTURE OF SEEDS

15. Germinating Seeds. The "higher plants" have their round of life from the seed to the mature plant, forming roots, stems, branches, leaves and flowers. Many crops of the farm and garden are started each year from seed. We should observe a number of the larger kinds of seeds, such as corn, beans, peas, cotton, squash, sunflower, castor beans, and any other large seeds that may be easily secured. After we have closely examined them as to their size, texture of their coverings, and other qualities, a number of each kind should be planted and observed in the schoolroom while they are germinating. They may

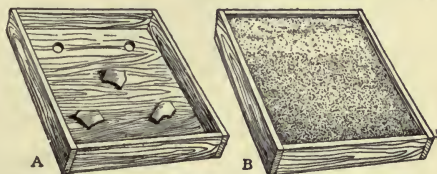


Fig. 7. Gardeners' flats. A, showing holes for drainage. B, filled with sand or loam ready for planting.

be planted out-of-doors if the weather is warm, but it will be much better to plant them in boxes of moist, clean sand or sawdust. A shallow box, 3 or 4 inches deep, like the gardener's flat (Fig. 7), will answer the purpose very well. After the seeds are planted, the box should be kept in a warm place. It may be kept covered with a pane of glass, to prevent the sand from drying out too rapidly. The student's germinating seeds will furnish fine study material for the class.

15a. Have the pupils make a list of all the common plants with which they are familiar that are started from seeds; also, those that are started from bulbs, roots, and cuttings.

16. Structure of Seeds. When we look at a bean, we see it is covered with a thin skin, or "seed-coat," which is quite smooth except at the edge where it was attached to the bean pod. Now, if we remove this coat from a



Fig. 8. Bean seed split open to show parts of plantlet.

seed (using one that has been soaked in water over-night), two large, thick "seed leaves," or *cotyledons* (cot-y-le-dons), joined to a minute stem, may be seen. (Fig. 8.) One end of the stem is round and plump, while the other bears two tiny leaves. The latter is the stem end, and bears the young bud. The root grows from the other end. Thus we see that the bean has all the parts of a plant, but a very small or embryo plant.

17. Stored-up Food in Seeds. Plants need food to build up their bodies and provide energy, just as animals do. The cotyledons do not look like ordinary leaves, because they are filled with much starch and other substances, to nourish the plantlet when it begins to grow. Substances stored up in seeds like this are called "reserve foods." The reserve food in the case of the bean is largely starch. In some plants it is largely oil, as in cotton seed, sunflower, pecan, flax, etc. Besides starch and oils, another class of substances is present as a reserve food of all kinds of seeds, called *proteids*. Proteids from animal bodies are familiar, as the whites and yolks of eggs, clabber of milk, clot of blood, etc. (See Appendix C.)

18. Corn. The corn "grain" is covered with a clear skin, or seed-coat.* If we cut through a corn grain, as shown in Fig. 9, we see a yellowish oily germ, or embryo, on one side, and a large starchy mass of additional reserve food stored back of the germ. When the reserve food is stored outside of the germ, it is called *endosperm*. The endosperm in the corn grain exists in two layers, one of which is starchy and loose, and the other clear and hard.

19. Cotton. In cotton, the seed-coat is covered with a layer of fibers, or lint. The hard brownish coat encloses an embryo cotton plant, with leaves closely rolled around the stem. The parts are best made out in seeds that have just germinated. Cotton seeds are very rich in oils and proteids.

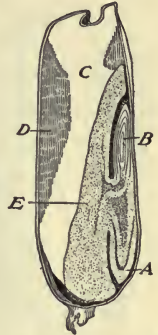


Fig. 9. Section of a grain of corn showing the parts of the germ or embryo corn plant (*A*, *B* and *E*), and position of reserve food. *A*, root end and *B* shoot end of embryo; *E*, the part of the embryo that absorbs the reserve food during germination; *C*, soft starch; *D*, horny part of reserve food.

QUESTIONS

1. In what other ways than by seeds may plants start new individuals? 2. Name the parts of a plant that are enclosed in a bean seed. Describe them as they are in the seed. 3. Of what use are the cotyledons? 4. What is meant by reserve food? 5. What substances may be present in reserve foods? 6. Describe the corn seed. 7. What is the essential difference between the bean seed and the corn seed? 8. Describe the cotton seed. 9. Is it most like the corn seed, or the bean seed? that is, in what part of the seed is the reserve food stored?

*In reality, the covering of a grain of corn is double, but the two coats are so closely united that it is difficult to distinguish them without special preparation. The outer coat corresponds to the pod, or seed-case, as in beans.

CHAPTER IV

HOW SEEDLINGS GET ESTABLISHED

20. Germination. Germinating seeds must have water, air, and a certain amount of warmth. The prompt-

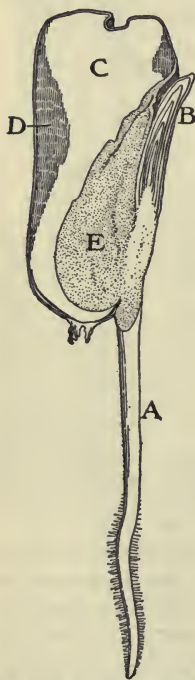


Fig. 10. During the early stages of germination the root grows faster than the shoot. A, root. B, shoot. C, starchy endosperm. D, horny endosperm.

ness of germination depends on how well these conditions are provided. In three or four days, seeds sown in moist sand will be found to be very much larger. They have absorbed water from the sand, so much so that the weight of the seed is now much greater than when it was dry. In some, the coverings of the seed will be found broken, and tiny roots pushing through. If they are watched for some days, it will be found that this tiny root grows in a downward direction, regardless of the position of the seed. The root makes a considerable growth before the young stem, with its tiny leaves, gets out of the seed case. (Fig. 10.) When the embryo plant inside the case begins to grow, we say the seed is *germinating*.

21. Root-hairs. The tiny rootlets which we found pushing through the seed coat are just like the thousands of branches found on roots of

older plants. They are very delicate, and it is better to grow the roots in moist air, to see the many minute root-hairs. On a seedling with root-lets an inch or more long, notice that just back of the tip it is covered with a very fine fuzzy growth. This fuzzy growth is composed of thousands of slender tube-like cells, called root-hairs. (Figs. 11 and 12.)

They are formed near the root's tip. After a time they die. They cannot be found on the root except for a short way from the tip. Unless the soil is very carefully washed from the rootlets, the root-hairs may not be seen. (Fig. 11, B.)

22. How the Root Absorbs Water.

Even though the seedlings that have been growing in sand or sawdust be very carefully washed, much of the sand or sawdust adheres to the hairs. (Fig. 12.) The root-hairs hold the soil

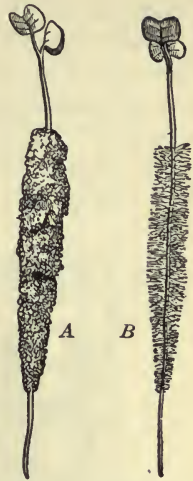


Fig. 11. Seedlings of mustard. A, with particles of soil clinging to root-hairs. B, after removal of soil by a stream of water. After Sachs.

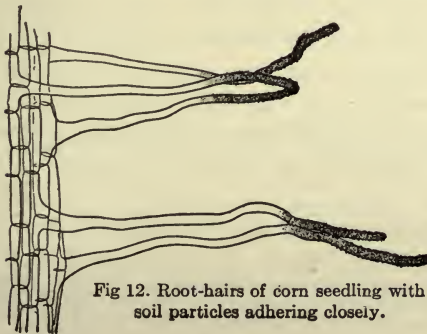


Fig 12. Root-hairs of corn seedling with soil particles adhering closely.

particles to the root. When the roots are growing in moist air, they are straight; but in the soil the hairs apply themselves very closely to the soil particles. (Fig. 13.) The water ab-

sorbed by the root is first taken in by the root-hairs. The seedlings may be growing in soil so dry that water may not be pressed out of it, still, the soil particles are covered with a film of moisture from which the roots absorb their supply. (See Fig. 39.)

23. How the Root Grows. The root grows only at the tip. The tip does not grow straight through the soil,

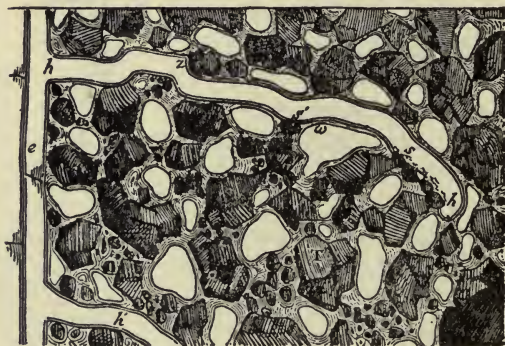


Fig. 13. Diagram of a portion of soil penetrated by root-hairs, *h*, *h'*, arising from root, *e*. At *z*, *s*, *s'* the hair has grown into contact with some of the soil particles, *T*, which are surrounded by water films (shaded by parallel lines). After Sachs.

but bends to and fro in a sort of circle, taking advantage of the small openings between the soil particles. It is covered with a delicate *root-cap*. As the root lengthens, the cells of the cap are rubbed off, but new ones are formed to take their place. Only the region in front of the root-hairs has the power of lengthening. (Fig. 14.)

24. Absorption of Water by Seeds. Seeds absorb water from the soil particles. When dry seeds are placed in a bed of moist sand or loam, the little film of moisture that covers the soil particles is absorbed by the seeds.

Seeds will not absorb enough water from moist air to make them germinate. They must be in contact with a substance covered with a film of water.

24a. The Swelling of Seeds. Place some common beans in a glass of water, and observe every few minutes. Where does the seed coat wrinkle first?

24b. Rate of Absorption Affected by the Amount of Water Present. Place a dozen seeds in . glass of water, a second dozen in wet sand, and a third dozen in slightly damp sand. Examine every day, and judge the amount of water absorbed, by the increased size and weight of the seeds.

24c. Rate of Absorption Affected by the Number of Points of Contact. Take two lots of seeds, corn for example, and place each lot in a tumbler or other vessel with the same amount of moist sawdust. In one, sprinkle a layer of

sawdust, and then a layer of seeds, then another layer of each, taking care that in one the sawdust is not pressed down, but kept very loose. Prepare the second vessel just as above, but press the sawdust firmly around the seeds. This increases the number of points of contact between the sawdust and the seeds. Cover, to prevent drying out, and examine the seeds at the end of every twelve hours. Does pressing the sawdust about the seeds make them swell more quickly?

24d. Prompt Absorption Hastens Germination. Sow some peas in a gardener's flat, filled with very loose sawdust. Press the sawdust

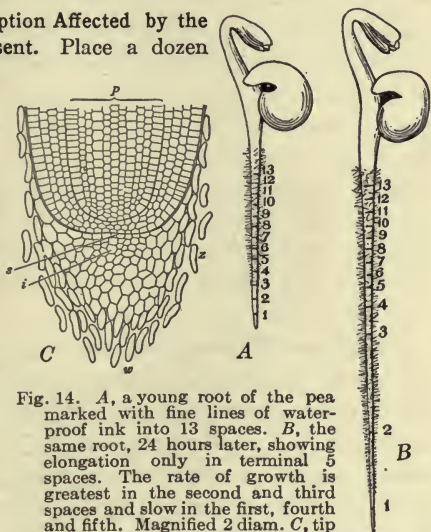


Fig. 14. A, a young root of the pea marked with fine lines of waterproof ink into 13 spaces. B, the same root, 24 hours later, showing elongation only in terminal 5 spaces. The rate of growth is greatest in the second and third spaces and slow in the first, fourth and fifth. Magnified 2 diam. C, tip of root greatly magnified and shown in section. *w*, root-cap; *i*, younger part of cap; *z*, dead cells separating from cap; *s*, growing point; *p*, central cylinder.

down firmly on one end and leave loose on the other. Cover with a glass, to prevent drying out, and note the time required for germination in the two ends.

25. Other Conditions affecting the rate of absorption of water by the seeds, are temperature, the nature of the seed-coat, etc. The seed covering of most cultivated plants will absorb and transmit the soil-water quite freely, though many seeds are provided with thick, bony shells, or coats, that resist the action of water for weeks, even months, if they once become dry. Such seeds are the peach, locust, walnut, and most wild seeds. Germination may sometimes be hastened in such seeds by soaking in warm water before planting; freezing while moist aids and hastens others, especially those having thick, hard shells, such as peach, walnut, hickory, plum, etc.

26. How Warmth Affects Germination. A certain degree of warmth is necessary before seeds will germinate. If we had placed in a refrigerator the seeds used in the experiment described in ¶ 15, the corn and beans would not have germinated, although they had plenty of water and air. This shows that a certain amount of warmth is necessary for germination. Some seeds, however, will germinate at a very low temperature, though they do not germinate quickly. The lowest temperature at which seeds will germinate is called the "minimum germination temperature." The highest temperature at which they can germinate and live is called the "maximum germination temperature." Between the highest and the lowest there is a temperature at which germination takes place quickly, but without injury to the seedlings. This is called the "optimum germination temperature." These temperatures have

been determined by trial for many kinds of seeds. The following results were reported by the celebrated German botanist, Julius Sachs:*

EFFECT OF TEMPERATURE ON GERMINATION

Kind of Seeds	Minimum or lowest between	Optimum or best between	Maximum or highest between
	Fahr.	Fahr.	Fahr.
Oats.....	32-41°	77- 88°	88- 99°
Pea	32-41°	77- 88°	88- 99°
Wheat.....	32-41°	77- 88°	88-108°
Indian Corn.....	41-51°	99-111°	111-122°
Sunflower.....	41-51°	88- 99°	99-111°
Pumpkin.	51-61°	93-111°	111-122°
Melon.....	60-65°	88- 99°	111-122°
Alfalfa.	88-99°	99-111°	111-122°

27. The Soil Should Be Warm before seeds are planted. If the soil is cold, or has a temperature just above the minimum temperature, germination will be slow, and many seeds will rot before the seedling is established. The soil should be considerably above the minimum temperature before seeds are planted. The variation in the minimum temperature required for germination in different kinds of seeds explains why some seeds can be planted much earlier than others.

28. Effect of Temperature on the Promptness of Germination. In some tests made by Professor Haberlandt, it was found that the seeds of most of the small grain crops required five to seven days to begin germination at 41° Fahr., while at 51° Fahr. only half the time was required. At 65° Fahr., one day was sufficient

*Julius Sachs, esteemed as the founder of modern plant physiology, was born in Breslau, 1832, and died in 1897. The great interest aroused by the results of his investigations on plant nutrition led to the establishment of one of the first public institutions for the scientific study of agricultural problems.

for wheat, rye and oats. Corn required three days, and tobacco six days. Sugar beets germinated in twenty-two days when the temperature was 41° Fahr., while, at 65° Fahr., germination commenced on the third day. (See ¶ 94, Temperature of Soils.)

29. Germinating Seeds Need Air. Growing plants, including germinating seeds, must have air. They use the oxygen of the air, and we call it *respiration*, just as we do in animals. While plants do not have lungs, they absorb the oxygen of the air and give off carbon dioxid. (But see ¶ 48, Carbon Assimilation.)

29a. To show that germinating seeds use the oxygen of the air, take two large fruit jars with good rubber bands. Into one put nothing. Into the other put a big handful of soaked seeds of corn or peas. Screw the tops on tightly and let stand for about twelve hours. Then carefully remove the top from the empty jar and thrust a lighted splinter down to near the bottom of the jar, noting the duration and brilliancy of the burning taper. The taper goes out after a time, because the burning of the wood uses up the oxygen in the jar. Now thrust a lighted paper into the jar with the germinating seeds, noting if it burns as brightly as in the empty jar. It goes out quickly because the germinating seeds have used up all the oxygen, and that carbon dioxid is present may be proven by lime-water poured down the side of each jar. The empty one gives no result, while the other will show a white band on the inside of the jar. This is the test for carbon dioxid.*

30. Not All Seeds Germinate. Seeds often fail to germinate when given the proper conditions for germination. This may be due to one or more causes. They may be too old; they may have been gathered when immature; they may have become too dry, or frozen when not sufficiently dry. Sometimes they become

*Carbon dioxid, exhaled from the lungs of animals and by germinating seeds, is a gas formed by the union of two elements—carbon and oxygen. Oxygen is a gas forming a large part of the air; carbon is a solid familiar as charcoal, which is crude carbon

damp and spoiled by molds. In many cases, insects injure them while stored. It is not usually possible to tell if seeds will germinate by looking at them.

31. Testing Seeds for Germinating Powers. If there is reason to think that a particular lot of seeds are not practically sound, they should be tested. It is a simple matter to test the germinating power of a sample of seeds. Several forms of seed-testing apparatus may be easily provided. Any arrangement will do that will allow us to place a counted number of seeds under the proper conditions for germination. Small seeds may be placed between moistened layers of clean cloth or soft paper. It is best to wash the cloth in boiling water before use, in order to lessen the liability to the growth of molds. Moist sand or saw-dust is very satisfactory for large seeds like corn, beans, etc. We will later learn more about testing seeds for yielding power(¶213a).

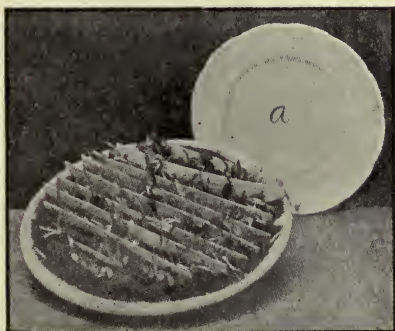


Fig. 15. A good seed tester. Clean sand and soup-plates.

31a. Farmer B. bought two bushels of alfalfa seed at \$9 per bushel, of which 95 per cent were viable, that is, capable of germinating. He was offered seed for \$8 per bushel, of which only 75 per cent would germinate. What was the actual cost of a bushel of live seed in each lot?

32. How Deep Should Seeds be Planted? Seeds should be planted just deep enough to secure the conditions necessary for germination. The soil is warmer near the



Fig. 16. Seed-testing devices

surface, but also dryer. If planted too deep, it will take a longer time to begin germination, because the deeper ground is colder, particularly so in early spring.

The table below shows the effect on the time in coming up, of planting wheat at different depths, and the number of seedlings that grew.

Depth	Time in coming up	Proportion of seed that grew
$\frac{1}{2}$ inch.....	11 days.....	$\frac{7}{8}$
1 inch.....	12 days.....	all
2 inches.....	18 days.....	$\frac{7}{8}$
3 inches.....	20 days.....	$\frac{4}{8}$
4 inches.....	21 days.....	$\frac{1}{2}$
5 inches.....	22 days.....	$\frac{3}{8}$
6 inches.....	23 days.....	$\frac{1}{8}$

The seedling will be more exhausted before it reaches

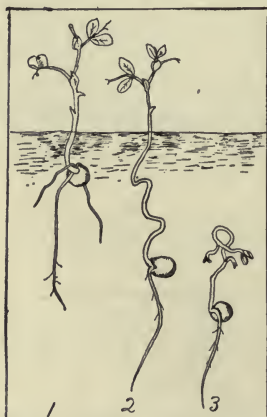


Fig. 17. 1, Pea planted just deep enough to be in well moistened soil; 2, too deep seedlings delayed in reaching surface; 3, too deep, unable to reach the surface.

the surface if planted too deep. The seedling stage is a delicate one. Success, therefore, in getting a good stand will often depend on how well the soil has been prepared for the seeds. The soil intended for the seeds should be warm, moist and mellow. The particles should be so fine that the seed will be in contact with grains of soil on all sides. Small seeds, like tobacco, are merely pressed into the surface with a board. With such small seeds, special arrangements should

be made to keep the surface from drying out until the young plantlets have sent their roots into the soil.

33. In Planting Field Seeds, it is often desirable to put them sufficiently deep to allow for some drying out of the surface soil. If planted very near the surface, hot winds will often dry the soil before the seeds absorb enough water to germinate. To produce quick germination, it is sometimes desirable to compact the surface by rolling. This puts the surface particles in closer contact with the seeds, and the moisture is absorbed more rapidly. In dry times, the seeds often germinate more quickly in the tracks made by persons walking across the field. Gardeners often pack the surface with a spade or board or roller, after sowing the seeds. When moisture is scarce in the soil, as is quite often the case at the planting time of field seeds, a most practical and successful way to secure the germination of seeds in drills is to make the laying-off plow or tool cut a deep V-shaped furrow in the compact soil, into which the seeds are dropped and covered to the proper depth with fine soil. This V-shaped furrow affords two banks of undisturbed soil holding a supply of moisture for the seed. (Fig. 18.)



Fig. 18. Planting seeds in the "water furrow" insures a more even supply of moisture.

34. Prompt Germination Important. Seeds that germinate quickly give more vigorous plants. Besides, seeds in the ground may be destroyed by insects, or caused to rot by fungi and bacteria, or rains may come and make a hard crust on the surface through which they cannot grow. Vig-

orous-growing weeds may crowd out slow-growing seedlings. Prompt germination may be secured under field conditions by thoroughly preparing the seed bed, and delaying planting until the soil is warmed sufficiently for the kind of seed to be planted. (See ¶ 27.)

35. Time Required to Complete Germination. The plantlets are nourished for a time by the reserve food in the seed. While the plantlet is dependent on this reserve food, it is called a "seedling." The root develops faster at first, with the result that the plantlet secures a more permanent supply of moisture from the deeper layers. The roots grow down or downward, and the stem and leaves grow upward into the air. The time required for the completion of the seedling stage will vary with the kind of seed and the conditions which affect germination. When conditions favor quick germination and rapid growth, the supply of reserve food is used up much sooner. Wheat seedlings will exhaust their reserve food in ten days in warm weather; but, if the temperature is low, it may be forty days before the plantlet is thoroughly established.

36. Hotbeds. It is often desirable to grow seedlings under artificial conditions, so that the plants may be ready for transplanting when the warm season comes. Many tender garden plants, such as tomatoes and cabbages, are propagated in this way. Coldframes and hotbeds are often used. A coldframe is an inclosed bed of soil that may be covered at night to protect from frost. A hotbed is an inclosed bed of soil, covered with glass, as shown in Fig. 19, which is warmed by the heat of fermenting compost placed below the bed of soil. Sometimes steam pipes are run below the seed-bed to supply the warmth.

QUESTIONS

1. Describe germination. 2. What are root-hairs? 3. What is their position on the roots? 4. What is the purpose of root-hairs? 5. At what place does the root grow? 6. How is this growing region protected? 7. What are the conditions necessary for germination? 8. Does the air contain enough moisture for germination? 9. Name some seeds whose seed-coats hinder quick germination. 10. How may this hindrance be overcome? 11. Why do not most seeds germinate in winter? 12. What is meant by "minimum germination temperature"? By "maximum germination temperature"? By "optimum"? 13. Discuss the relation of soil, and the time of planting, to these temperatures. 14. Give in substance the results of Professor Haberlandt's experiment in regard to the effect of temperature on the promptness of germination. 15. What necessary food does the plant get from the air? Does the plant breathe in the same gas that we do? 16. Name some of the causes of failure in germination. 17. What are some of the conditions of successful seed-planting? 18. What are coldframes? hotbeds?

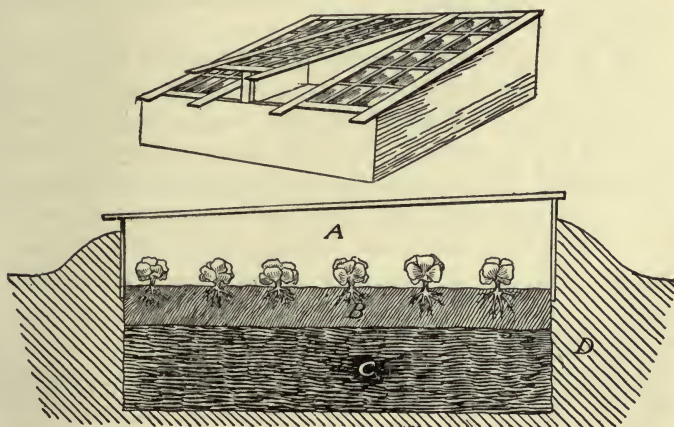


Fig. 19. Hotbeds and coldframes. The upper figure is a coldframe. If let down into the soil and warmed by fermenting compost, it is called a hotbed. A, Warm air; B, garden loam; C, fermenting compost; D, bank of soil.

CHAPTER V

PLANT SUBSTANCE

37. The Body of a Plant, including stem, root, seeds, etc., is composed chiefly of framework material and reserve food. The framework material is never used by the plant for any other purpose. The reserve food contains a variety of substances. Sometimes this reserve food is separated by mechanical means in an almost pure condition, such as starch from corn and potatoes, cooking oil from cotton seed, linseed oil from flax seed, castor oil from castor beans, corn oil from corn, and peanut butter (a thick oil) from peanuts. When the starches and oils are thus removed, there still remain the bran and meal, which contain a variety of food substances.

38. In Germinating Seeds, all the reserve food may be used to nourish the young plant. The substances in the thick cotyledons of the bean were seen to wither away as the seedling grew. The store of food for the young plant in the seed was put there by the parent plant. A corn grain will produce from one thousand to two thousand seeds and a large stalk. Where does the seedling get all the food materials to nourish so large a stalk, and lay up a large store for so many other seeds? Before we answer this question, we will try to find out something of the nature of the substances in plants.

39. Composition of Plant Substance. Chemists have ways of separating the various substances found in

plants. They find that every plant contains a variety of substances, though the quantity and number vary in different kinds of plants. Some plants, as corn, contain much starch in their seeds, and but little in the stalk. Some plants have a large amount of sugar, as beets and sugar-cane, while others contain oil. These substances which we call starch, oils, sugars, proteids, resins, gums, acids, etc., are themselves compounds of a number of "elements." The carbon mentioned in ¶ 29 is an element. So are iron, sulphur, lead and the oxygen of the air.

40. Compounds of Elements. A simple element is a substance of a peculiar kind that cannot be reduced by analysis to any simpler state. When wood burns, the carbon (an element) of the wood combines with the oxygen (an element) of the air, to form an invisible gas, known as carbon dioxid (a compound). When iron "rusts," it has formed a compound with the oxygen of the air. In germinating seeds, the oxygen absorbed is afterward given off as carbon dioxid. Oxygen combines with another element which we call hydrogen, to form the substance we call water. Thus we see that the same element may combine with a number of other elements, making a different compound or substance with each combination.

41. Substances Found in Plants are usually complex compounds of the simple elements; for instance, starch is a combination of carbon, oxygen and hydrogen, and the properties of the substance we call starch are different from any of its parts. Sugar is composed of these same elements, but has them combined in a different way. Wood is composed of the same three elements, yet combined in still a different way.

42. Protoplasm, or living substance, has the power to combine simple compounds to form the complex ones that compose the plant or animal body. Living green plants absorb water and mineral matter from the soil and carbon dioxid from the air, and with these form the complex plant substances. Light is needed by the leaves in making these combinations.

43. Elements Necessary for Plant Growth. There are about eighty different elements known, but only about a dozen are actually used by plants. The following elements are necessary for the healthy growth of plants: (1) *Carbon*, absorbed by the leaves from the air as carbon dioxid; (2) *oxygen* and (3) *hydrogen* taken in as water; and the following, all taken in by the roots from the soil solutions as soluble salts: (4) nitrogen, (5) phosphorus, (6) potassium, (7) calcium, (8) magnesium, (9) sulphur, (10) iron, and (11) chlorine. Other elements are often found in plants, but only the ones named above are really essential. If any one of these essential elements is withheld from the plant, the normal growth is impaired. The importance of the mineral substances to the welfare of plants will be discussed later. (See Chapters XII and XIII.)

44. Non-essential Elements in Plants. Besides the essential elements named, plants usually contain other elements that are really not necessary for their normal growth. The most common ones are sodium (the principal element in common salt), and silicon, a constituent of sand.

45. The Amounts of the Elements in the Plant Body. About half of the plant substance is carbon. It is a part of practically all compounds found in plants. Oxygen and hydrogen, too, are parts of nearly all

substances in plant and animal bodies. Nitrogen is always present in the living substance, or protoplasm. The other elements, usually called the "mineral elements," while absolutely essential, occur only in small amounts, usually less than five per cent. These elements form the "ash," when plants are burned.

NOTE.—It is important that students should have a reasonably clear notion of the properties of matter, what an element is, and the differences between a mixture, a solution, and a chemical compound. Some simple experiments will prove very helpful in this connection, such as the burning of a match, a lamp, or a sulphur or tallow candle, with a discussion and explanation of the phenomena in each case. Likewise, experiments involving the dissolving of salt or sugar in water, and its subsequent recovery by the evaporation of the water, should be performed and discussed fully.

QUESTIONS

1. Name some of the reserve food substances. 2. What is meant by a "chemical element"? Name some common ones. 3. Do plants contain simple elements? Name three plant materials that contain the same elements combined differently. 4. By what means does the plant manufacture complex compounds out of simple compounds? 5. Name the elements essential for plant growth. 6. Name the most common non-essential elements in plants. 7. What are the proportions of the elements in plants?

CHAPTER VI

HOW THE PLANT INCREASES ITS SUBSTANCE

46. The Work of Leaves. The leaves are the food factory of the plant. Perhaps you have never thought to ask why most leaves are flat. You will find a suggestion of the answer if you note that their flat faces are usually turned toward the source of the strongest light. Look at a tree, to note the position of the leaves, as seen from a distance and from among the branches. This position is an advantage to the leaf in carrying on its work, because it secures the greatest amount of energy from the sunlight for the food-making process.

47. Structure of Leaves. A thin section of a leaf, when examined under a powerful microscope, is seen

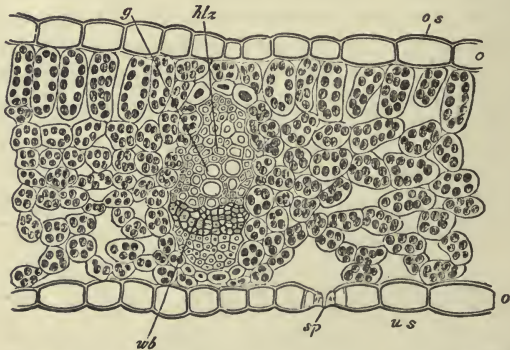


Fig. 20. Cross-section of a leaf through a "vein," or fibro-vascular bundle. *Os*, upper surface; *us*, under surface; *o*, layer of outside cells forming the epidermis; *sp*, Stoma; *g*, water duct; *wb*, phloem; *hlz*, wood cells of fibro-vascular bundle.

to be composed of a great number of cells. The surface layer forms a skin, or "epidermis," which keeps the cells within from drying. (Fig. 20.) The epidermis is in two layers. The outer, or cutin layer, is only a thin membrane which, while transparent, to allow the light to reach the inner tissues of the leaf, is impervious to water.

The second layer is a tier of cells which support the cutin layer. This epidermis is very efficient in keeping the water in the leaf. On the lower side of the leaf, and on both sides of some leaves, there are many small openings, to let the carbon dioxide enter and the excess of oxygen pass out

when the plant is making food. (Fig. 21.) Some water escapes through these openings, or *stomata* (singular, *stoma*); but at night, when the food-making processes are not going on, these stomata close up, so that much less water escapes.

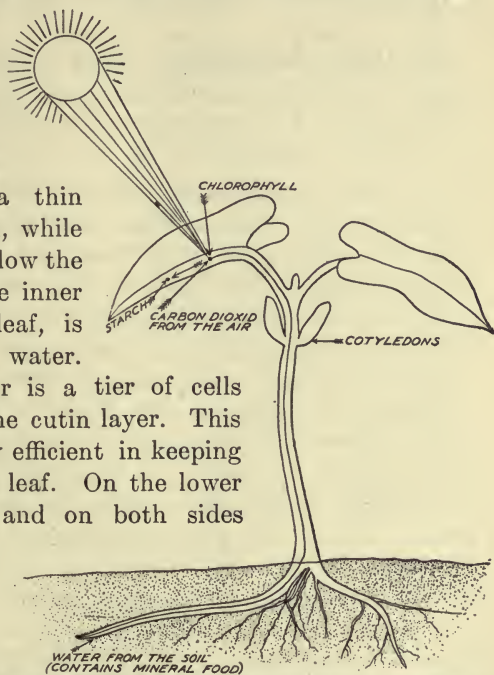


Fig. 21. How the young plant gets its food. In the early stages it is nourished from the store of food in the cotyledons. When the green leaves unfold to the light they absorb the energy of the sunlight and cause the water to combine with the carbon dioxide of the air to form starches and other foods.

47a. To get an idea of how well the epidermis protects the

plant, take an apple or potato and peel off the epidermis and place in an exposed place beside an unpeeled specimen. Note how quickly the peeled specimen will shrivel and dry, while the other retains its form.

48. Carbon Assimilation. The soft tissue between the upper and the lower epidermis is the real food factory of the plant. It is composed of several layers of cells, all arranged sponge-like, so that the carbon dioxid of the air can reach every cell. All these cells contain minute green bodies, called chloroplastids (chlo-ro-plast-ids). The green coloring matter in these bodies is formed only in the light. It does not form in leaves growing in the dark. The yellowish stems of potatoes growing in dark cellars is a familiar example. The green color will disappear if plants are kept from the light. Advantage is taken of this property in "blanching" celery. When the light shines on the leaves, the chlorophyll absorbs the energy of the sun's rays and forms the starches, sugars, etc., from the water and carbon dioxid. This process goes on through all daylight hours. (1) *Light*, (2) *living cell with* (3) *chlorophyll*, (4) *water and* (5) *carbon dioxid must all be present*. This explains why plants do not grow unless they get plenty of sunlight. This process of making plant substance under the influence of sunlight is called "carbon assimilation." It is not confined to the leaves, but takes place in any green cell when the other conditions exist. (See Figs. 20 and 21.)

49. How Green Plants Purify the Air. When carbon dioxid combines with water, the excess of free oxygen of the carbon compound escapes into the air. By this means, growing green plants purify the air. They take up the carbon dioxid given off from the lungs, or that

formed by burning of plant or animal bodies, and retain the carbon, the oxygen being set free. But this oxygenizing power of plants is much less than is generally supposed; for the respiratory process of plants, giving out carbon dioxid partially counteracts the effect of the assimilative process. Carbon assimilation does not take place rapidly in a subdued light, such as exists in an inclosed room.

50. Importance of Carbon Assimilation. With one or two minor exceptions, this process of food-making is the only known means of increasing the supply of food for both plants and animals. We can now answer the question asked in ¶ 38. By this process the corn plant is able to reproduce itself many fold and, also, "tall oaks from little acorns grow." No animal has this power to form food substances from the simpler compounds. It is plain, therefore, that the farmer's stock, and indeed all life, is dependent upon plant life for food. More than one-half of everything grown on the farm is carbon drawn from the air.

QUESTIONS

1. Why are most leaves flat? 2. Describe the layers in a leaf. 3. Which layer manufactures food? 4. Describe carefully how the carbon of the air gets into the leaf. 5. Is light necessary for the formation of the green color in leaves? 6. What is the effect of continued darkness on green plants? 7. Name the five necessary conditions for the making of plant substance. 8. Discuss the importance of food-making by plants.

CHAPTER VII

THE WATER IN PLANTS

51. Why Plants Need Water. Plants use water in three essential ways: (1) It combines directly with carbon dioxid to form plant substance; (2) it acts as a solvent for the minerals absorbed from the soil; (3) it serves to make the plant rigid. Young, succulent stems are dependent on water for their rigidity. If water escapes, they wilt and lose the power of carrying on their work. Water is necessary for plants in other ways. It is present in all parts.

52. The Movement of Water within the Plant. There are special channels for conducting the water from the roots to the stems and leaves. The water is absorbed by the roots and is transported in special water-conducting vessels through the stem and leaves. These channels may be easily marked by placing the soft stem of some plant in a glass of blueing or of diluted red ink. The coloring matter will be carried along with the water and the path through which it moves will be shown. This experiment should be made and closely observed by all. Cut cross-sections of the stem to notice the channels through which the water travels. Leafy stems of balsam, begonia, Johnson grass, poke-berry, and other common plants, make good illustrations.

53. The Amount of Water in Plant Substance is considerable, as may be seen from the following table showing the approximate amount of water in a number of common plants.

APPROXIMATE AMOUNT OF WATER IN PLANTS

	In fresh plants— water in 100 lbs.	In air-dry plants— water in 100 lbs.
	Average	Average
Alfalfa	72	8.4
Prairie Hay	70	30.0
Corn Stalks	82	34.0
Potato Tubers	75	....
Corn Grain .....	....	10.0
Turnips	91	....
Grain straw .....	....	9.0
Small grains .....	....	9 to 12

53a. How many pounds of water in a ton of freshly cut alfalfa? How many pounds of water in a ton of air-dry, or cured alfalfa?

54. Loss of Water by Plants. Plants lose water through the stomata in their leaves, and their other parts to a slight extent. Some plants lose water very slowly, even under very dry conditions, as, for instance, the cactus on the dry, open prairies. It has been estimated that ordinary cultivated plants lose water by transpiration about one-fifth to one-tenth as fast as it would evaporate from a surface of free water. In times of drought, when the air is very dry, transpiration will be greater than under ordinary conditions. Hot, dry winds increase the rate at which water escapes from the plant. (See ¶ 98, How Plants Dry the Soil.)

55. Drought-resistant Varieties of cultivated plants have coverings that prevent the ready escape of water. This may be seen in the varieties of corn imported from dry countries, which have thicker leaves and coarser shucks than the native kinds.

QUESTIONS

1. In what three ways do plants use water? 2. How does the plant get water? 3. How does the plant lose water? 4. How do drought-resisting plants prevent the escape of water?

CHAPTER VIII

STRUCTURE AND WORK OF STEMS

56. The Primary Use of the Stem is to hold the leaves up where they may be fully exposed to the light. Sunlight furnishes the energy for the food-making work. Of course, when the leaves are more exposed to the light and winds, evaporation is increased. Therefore, stemmed plants need more water than stemless ones.



57. The Growing Point of the Stem is in the bud at the end. The cells at the growing tip are very small and delicate. The young sections, or internodes,* grow in length, forming the stem. The stem lengthens by the multiplication and growth of the cells. All the cells are much alike at first, but, as the cells lengthen, so does the stem. Many changes take place. Soon there are several kinds of cells and vessels, as shown in Fig. 22. Some are elongated,

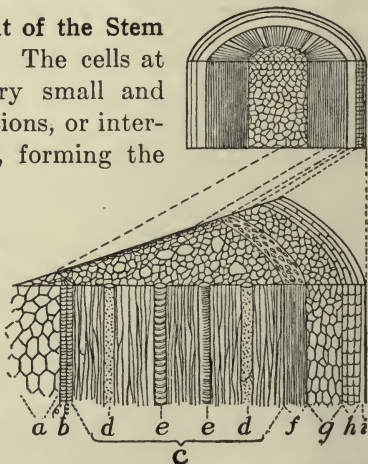


Fig. 22. Cross-section of a woody stem. Upper one actual size. *a*, pith; *b*, *d* and *e*, water ducts; *c*, woody portion; *f*, phloem; *g*, *h*, and *i*, outer protective layers. After Goodale.

*The use of the words *nodes* and *internodes* is made necessary by the double use of the word "joint."

thick-walled, woody fibers, arranged with overlapping ends cemented together, thus stiffening the stem. The water-conducting vessels are surrounded by these woody fibers. In some grasses and grass-like plants, the water vessels and wood fibers are united into strands forming the "threads," or fibro-vascular bundles, embedded in a mass of soft pithy tissue. This condition is well illustrated in the stalks of corn. The strands (Fig. 23) in the pith are bundles of woody fibers surrounding the water-conducting channels. Plants having the veins of the leaves arranged like a net have the water-conducting vessels in the woody part. (Fig. 22.) In young stems they exist as separate

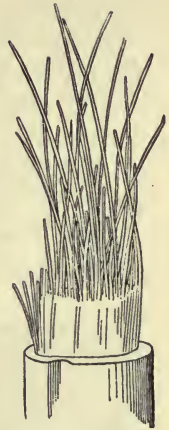


Fig. 23. Corn-stalk, showing fibro-vascular bundles, or "threads."

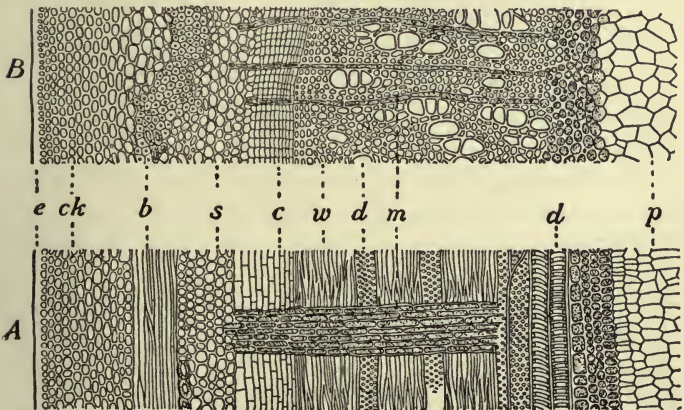


Fig. 24. Cross-section (B) and longi-section (A) of stem, greatly magnified. P, pith; d, d, water ducts; m, medullary rays; w, woody portion of stem; c, delicate cambium or growing cells; s, phloem of food-conducting cells; b, hard fibers; ck, cortex; e, epidermis.

bundles, but with age become so numerous that they unite to form the solid woody portion of the stem. Outside of this woody region is a layer of very thin-walled cells that are actively dividing and growing. This is the cambium layer. (Fig. 24c)

58. Cambium. The cambium is the region of active growth in the stem of plants with netted veined leaves. It causes the stem to increase in diameter by adding layers of cells each season, forming the *annular rings*.

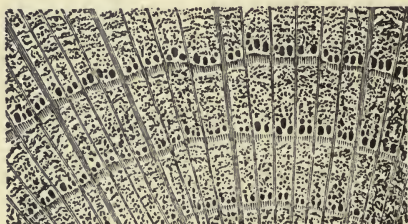


Fig. 25. Cross-section of an oak stem, showing the "annular" rings at J, which mark the close of the growing season.

(Fig. 25.) The cambium cells on the inner side become wood cells and water ducts, while the cells on the outside are gradually transformed into the food-conducting channels, or

phloem, just under the bark. The increasing thickening of the stem breaks the outer bark in long, vertical slits, and new bark is formed below.

59. Wounds made by pruning, gnawing of rabbits, breaking of branches, and other agencies, are often healed over by the growth of the cells of the cambium. Whenever the cambium cells form an extra growth in this way, it is called *callus*. Where large limbs are removed, it takes several years for the callus to grow over the wound. When trees are pruned, the exposed part should be heavily painted, to protect it till the callus can have time to grow over entirely. (See ¶ 186, How to Make the Cuts in Pruning.)

60. The Phloem Portion of the Stem is important, because it is the channel through which the food substances are carried from the leaves to the roots. The water moves up through the woody portion, but the food material moves in the phloem part of the stem. When land is cleared of large trees, the stumps will continue to form water sprouts for a long time, unless the trees are first "deadened." This is done by cutting off the bark entirely around the trunk of the tree, thus leaving a strip or girdle of the wood exposed. This does not cause the immediate death of the tree, because water can move up to the leaves through the stems, as before. However, no food can pass down to the roots, and they finally die of starvation. When the roots die, water is no longer absorbed, as the living root-hairs are gone. Girdling kills trees by starving the roots. (Fig. 26.)

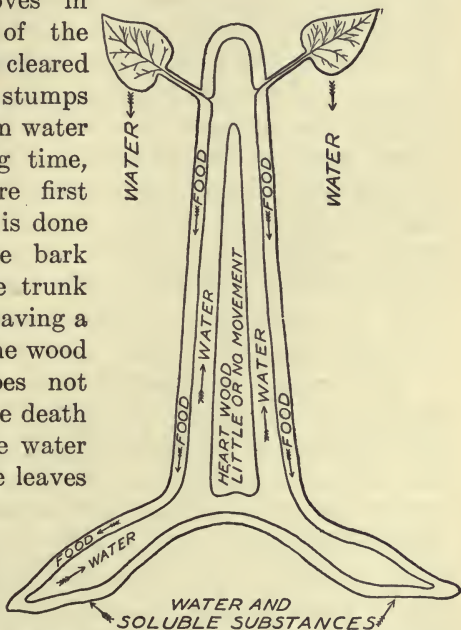


Fig. 26. Diagram to show the path of movement of water and reserve food substances in stemmed plants.

61. Roots May Die without Girdling. When fruit trees overbear, nearly all the food formed in the leaves goes to mature the fruit, and not enough goes down to

nourish the roots, hence the trees often die early in the following spring. Sometimes a severe drought prevents the trees from forming sufficient food, or insects, fungous diseases, or storms destroy all the leaves. All the reserve food is used up in an effort to form new leaves, and the roots die of starvation. Transplanted trees that fail to make a good growth often die at the beginning of the second spring, because of the exhaustion of their reserve food.

62. Perennial Weeds and sprouts from stumps may be killed by constantly destroying all leaf growth. Even though it does not kill them completely the first season, it may weaken them to such an extent that they may be more easily killed by other means. If allowed to grow to considerable size, the roots will receive food materials sufficient to start vigorous new growth.

63. Grasses and Weeds, like Johnson grass, that form thick rootstocks are difficult to destroy. They may be killed much more easily if they are kept grazed down, so that the leaves do not have a chance to form a store of reserve food for rootstocks. The half-starved rootstock is much more easily killed than the fully nourished one. Roots and other parts of plants, when poorly nourished, are more easily killed by exposure to cold, heat or drought. Hence, if such rootstocks are prevented from forming leaves they may die more quickly when exposed by plowing.

63a. Make a list of the common weeds found in the fields, orchards and gardens, in the community. Make a classified list, putting all that come up from seed and mature a crop of seeds before the middle of the summer [spring annuals] in one column; all that do not form seeds until late summer or fall [annuals] in a second column; and in a third column name all that live over winter by underground roots, stems or root-stocks.

64. The Storage of Reserve Food. Annual plants use their food supplies as fast as formed, in developing the shoots and roots, and, particularly, in forming flowers and fruits. Some plants, like turnips, cabbage, radish, etc., store the surplus food in the stem, leaves or roots during the first season, and use it during the next season to nourish a large crop of seeds. If grown in warm climates, these plants will complete the cycle in one season. In plants that live from year to year (perennials), food is stored up in the stems and roots, to supply the needs of the dormant season, and also to form the new crop of root-hairs, leaves and flowers in the following spring. It is the reserve food in the stems that makes the callus and new roots in cuttings of roses, privet, grape, etc. (See, also, ¶ 159.)

QUESTIONS

1. Where is the growing point of the stem? 2. What changes take place as the stem lengthens? 3. What is the difference in the arrangement of wood fibers and water vessels in the corn stalk and in plants with netted-veined leaves? 4. Where is the cambium, and what is its work? 5. How are the wounds on plants healed? 6. What is the position and use of the phloem layer? 7. Why are trees girdled? 8. How else may the roots of a tree be starved to death? 9. How may perennial weeds be killed? 10. How may Johnson grass be killed? 11. What are the uses of reserve food?

CHAPTER IX

THE PLANT AS RELATED TO THE SOIL

65. The Welfare of Plants is dependent on the nature of their surroundings. In cultivation, the effort is to make and keep the environment favorable. In open-field culture, little can be done to change the air, the temperature, or the amount of light. While the difficulty of changing the environment of the plant above ground is great, much may be done to control the environment under the ground. The fertility of the soil, the amount of water, the temperature, the supply of air, and other conditions affecting the growth of the root, may be readily changed. A knowledge, then, of the habits and needs of roots, and of how to make the soil conditions favorable, will be very practical information.

66. Uses of the Soil to Plants. (a) *Serves as a foothold.* The roots enter the soil and act as braces to keep the plant in the proper position. Plants with long stems and heavy foliage must have strong roots to enable them to withstand the action of the winds and other forces that would displace them.

(b) *Supplies the plant with important mineral foods.* The amount of food which the plant takes from the soil is small, as has already been seen, only about 5 per cent of its dry weight; yet, small as it is, these mineral foods are absolutely necessary.

(c) *The soil acts as a storehouse for water.* The plant

must have a continuous supply of water. The soil is able to store up water in the tiny spaces that separate its particles. The roots penetrate the soil and take up this water as the plant needs it. Plants can not take up solid food. All food substances must be dissolved before they can be absorbed. Hence, water is important, not only as a food, but also as a solvent for the particles of soil. The solutions pass through the thin, delicate membranes (cell-walls) of the cells (the root-hairs) by a process known as osmosis.

(d) *It retains and regulates the temperature.*

56a. Absorption of Water by Roots Illustrated.

The upward movement of water absorbed by plants may be easily illustrated in various ways. A good way is to cover the end of a lamp chimney with parchment paper, as shown in Fig. 27; then fill one-fourth full with syrup. Support the chimney in a vessel of water, with the syrup at the level of the water. After a time, it will be found higher, due to the absorption of water through the membrane. It acts like a large root-hair, which absorbs water from the soil and forces it upward into the stems and leaves. The water would

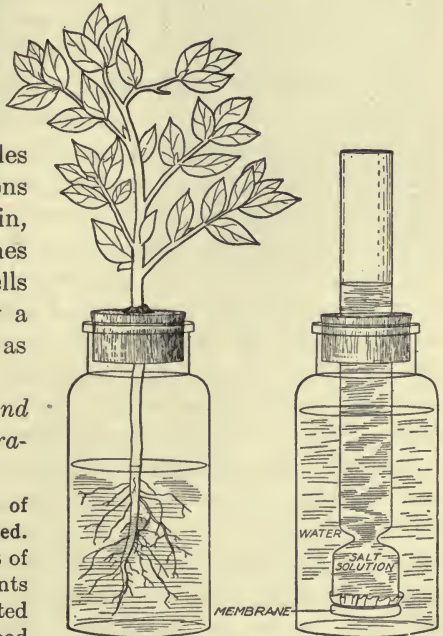


Fig. 27. To illustrate the absorption of water by roots. The plant absorbs water against the force of gravity. So will a salt solution.

not be absorbed unless the chimney contained the sugary syrup or some similar substance. It will be recalled that syrup is boiled-down sap from cane plants.

A solution of salt in the chimney would cause the water to be absorbed in the same way as the syrup, because salt, like sugar, makes the solution stronger and denser. Where two liquids are separated by a membrane, more water always goes through into the stronger solution. The bulk of the liquid in the chimney is thus increased, and is forced higher in the chimney.

67. Conditions Favorable for Root Growth. Not all plants require the same conditions for perfect development. All require some degree of moisture. Some plants do best when their roots are totally submerged in water, as the water-lily. Some land plants will grow with their roots in water, though they do best when the roots are in soil that contains plenty of air as well as water. When roots grow in a moist and very fertile soil, they are short, but have hundreds of little branches. This gives them a large absorptive surface, enabling them to readily take up the water and mineral food. When the soil is poor, or insufficiently supplied with moisture, the roots grow long and slender and have few branches. This does not mean, as some suppose, that the roots are "searching for food." When in a fertile soil, roots multiply rapidly, because they are well nourished. When in a poor soil, where the mineral food and water are insufficient, the leaves are unable to supply the roots with enough sugar, oils, proteids, etc., to make the roots multiply and grow rapidly. It has already been observed that roots will not grow vigorously when the oxygen of the air is excluded. Plenty of air is necessary for vigorous growth.

67a. To Show that Air is Necessary for Root Growth, use two jars, one filled with well-water, as shown in Fig. 28, and the other

with freshly boiled well-water. The water should be boiled to drive out all the oxygen, and a layer of cooking oil used to prevent more being absorbed from the air. Insert cuttings of willow or Wandering Jew, and keep in a warm place for a week or more. Note the time when the rootlets appear on the cuttings.

68. Moisture Promotes Root Growth on Stems. A continuous supply of moisture stimulates root growth. Portions of stems kept in contact with moist soil for some time develop roots, as is often noticed in fallen corn stalks, tomato vines, and potatoes. To make roots develop on cuttings of roses, figs, grapes, etc., we bury them in moist sand, loam, or sawdust. (See ¶194, Layerage.)



FIG. 28. To show that roots need air. See Paragraph 67a. From First Book on Farming. See Appendix A.

69. The Ideal Soil for cultivated plants is one having an abundant supply of moisture, containing plenty of soluble plant food, and so porous that air can circulate freely and come in contact with the roots. The soil may be too dense, or so compact that the air and water cannot circulate. It may be too wet,—that is, have so much water that all the air is forced out. In very wet weather, the roots are often noticed growing out of the surface of the ground.

70. Improving the Tilth of the Soil. We have already learned that the particles of the soil should be sufficiently fine for the root-hairs to grow between them. The particles may be so fine and so run together that neither the air nor the root-hairs can enter the soil. This condition is just as unfavorable for the roots as the coarse, lumpy soil. The texture, or physical con-

dition, of the soil in either case would have less water-storage space, and be less liable to set free liberal supplies of plant food. Some soils are so porous and loose that the moisture drains away, and the air circulates so freely that they dry out too rapidly.

71. Capillary Attraction is that force which causes water to rise in tubes or between particles of solid substances. The narrower the tube the higher will the liquid rise against the force of gravity. Fine-grained soils having smaller pores or spaces between their particles than coarse-grained soils, will lift water from below nearer to the surface than will coarse-grained soils. They will also hold more moisture in saturation than coarse soils, hence, are generally the better. Therefore, thorough tillage of the soil is beneficial.

72. The Problem in Soil Management is to bring the soil to an ideal condition for the healthy growth of the roots. Some soils must have the particles made finer, and some must be made coarser by causing the finer particles to combine.

73. How to Improve the Texture. Good texture is important and dependent on the size of the soil particles. In soil treatment the object, then, is to find the best means of modifying the size of the particles until the soil is mellow and friable. There are three general ways of changing the texture of the soil:

(a) *By applying mechanical force*, as in the operations of spading, plowing, harrowing, etc. This acts directly to make the particles finer. If heavy clays or black waxy land are tilled while wet, the particles are forced closer together, and we say the soil is "puddled." This is a brickmaker's term. In making brick,

the first effort is to destroy the granular texture, which is done by wetting and working the clay. Puddled clays do not crumble when dried before baking. Neither will a soil puddled by plowing when too wet crumble into fine particles in drying. (See ¶ 105 and Fig. 40.)

(b) *By exposing the soil to the weathering influences* of the air, frost, sun, snow, etc. When a lump or clod of stiff soil is left exposed to the alternate wetting of the rain and drying of the sun, it breaks up into many smaller particles and becomes mellow. Without this weathering effect, much of our plowing would be worse than useless. The land often breaks up cloddy, but in time it becomes mellow and loose. (Fig. 29.) It requires time. In order that a soil may be in the best condition for seed-ing, plowing should be done long before planting time so that the weathering influences may have ample time to perform their work thoroughly. Some soils will weather or crumble promptly, while

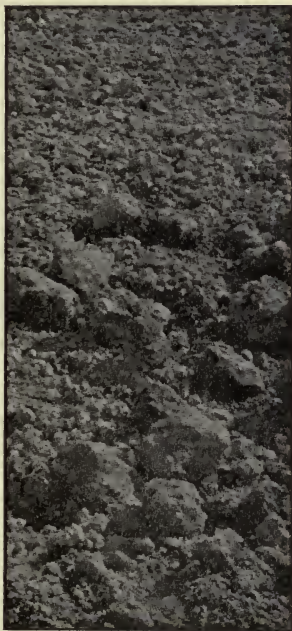


Fig. 29. Waiting for time and the rains to mellow down the clods.

others, like clay, require more time. Under this head should be included some of the effects following under-drainage. (See Fig. 41.) The surplus water is thus carried off and air takes its place, and the soil particles crumble.

(c) *By applying substances which act chemically or physically upon the particles.* These are called amendments, or indirect fertilizers. Lime is a familiar example. It renders many stiff clay soils mellow, and cements or binds together the particles of a sandy soil. Fertilizers are also amendments, because they act to modify the texture of the soil as well as to supply mineral plant food. Evidence is not wanting that the good effects of a fertilizer are sometimes much greater than the amount of mineral food supplied would allow us to expect. This is probably due to the effect of the fertilizer on the texture of the soil particles. It is especially true of composts, for they serve not only to supply plant food, but also to improve the texture of the soil.

74. The Texture of the Soil affects the yield of crops to a striking degree. To improve the texture is often equivalent to an application of a fertilizer. One farmer will raise as much on twenty-five acres as another will raise on forty acres. A gardener will raise as large a plant in a small pot of soil as a farmer does in a yard of soil. It seems that the surface exposed to the action of the root-hairs in the pot of soil may be equal to the yard of imperfectly prepared soil in the field.

75. A Soil is in Good Tilth when the particles are small enough for all the root-hairs to find a surface upon which they may act. A soil in good tilth exposes a large surface to the slow action of water, air and roots. (Fig. 30.) A coarse, lumpy soil may contain an abundance of plant food, but still make poor crops. If we take a cube and cut it into halves, we increase the surface exposed by one-third; we add two sides. By dividing again, we increase the surface in the same ratio. It will be seen that a lump of soil, when sufficiently fined to be in good tilth, exposes a

large surface to the action of the root-hairs. Professor King has figured out the result.* "Suppose we take a marble exactly one inch in diameter. It will just slip inside a cube one inch on a side, and will hold a film of water 3.1416 square inches in area. But reduce the marble to one-tenth of an inch and at least 1,000 of them will be required to fill the cubic inch, and their aggregate surface area will be 31.416 square inches. If, however, the diameter of these spheres be reduced to one-hundredth of an inch, 1,000,000 of them will be required to fill a cubic inch and their total surface area will be 314.16 square inches. Suppose, again, that the soil particles have a diameter of one-thousandth of an inch. It will then require 1,000,000,000 of them to completely fill the cubic inch and their aggregate surface area must measure 3141.59 square inches." All in one cubic inch of soil. When all the surfaces are moist, it is then perfectly plain why a fine soil will withstand more drought and give more root-feeding surface than a coarse soil.

76. Root-Hairs Absorb Plant Food. Root-hairs absorb the water that covers the soil particles as thin films.

*King, *The Soil*.



Fig. 30. A soil in good tilth.

They also take in some of the substances that are dissolved in the soil moisture. Root-hairs give off carbonic acid gas and possibly other acids, which help to dissolve some substances in the soil. This may be easily demonstrated by allowing roots to grow on a polished marble slab.

77. The Amount of Root Growth is large. A plant must have a large root surface to absorb enough water to make up for the loss from a large leaf surface. A large leaf surface is, of course, beneficial, because it means so much more surface for absorbing the carbon dioxid and energy from the sun's rays. There must, however, be a balance between the activities of the root surface and the leaf surface.

78. The Distribution of Roots in the soil varies with the kind and condition of the soil, but, roughly, the



Fig. 31. When trees are dug up, the large roots are found spreading in the first few feet of soil. These roots had a spread of forty feet.

roots are said to spread through an area equal to that shaded by the branches. Only in exceptional conditions do the roots extend very deeply into the soil. Even in forest trees, the most vigorous roots are found in the first foot or two of soil. In young trees, the tap-root is often noticed to grow directly down for some distance, but, when the trees are old, the side roots will be found to be many times larger. (See Fig. 31.)

79. The Total Length of the Roots is very great. Hellriegel* noted that a vigorous barley plant in a rich porous garden soil had one hundred and twenty-eight feet of roots, while another growing in coarse-grained, compact soil had only eighty feet of roots. One-fortieth of a cubic foot sufficed for these roots. It may be readily understood that all the soil was occupied. Professor Clark, after making a number of measurements, estimated that a vigorous pumpkin vine had fifteen miles of roots and gained one thousand feet per day. Professor King, of the Wisconsin Experiment Station, estimates that if all the roots of a vigorous corn plant were put end-to-end they would measure more than one mile in length.

80. The Vertical Distribution of Roots is affected to a large extent by the depth of the plow line, particularly so on stiff clay soils. The roots extend much deeper in dry seasons than in wet ones. These facts have been found out by carefully washing the soil away from the roots, leaving them supported on poultry netting. These observations are easily explained when we consider the effect of tillage on soil conditions. Fig. 32

*Herman Hellriegel (1831-1895) devoted his life to the study of the chemistry of plant nutrition. He was the first to discover the relation of the bacteria causing the tubercles on the roots of legumes to the fixation of free nitrogen. He made many other important discoveries in agricultural science.

illustrates the appearance of the roots of a corn plant at silking time.

81. Shall Crops be Tilled Deep or Shallow? It is important that we know the distribution of the roots in the soils that are cultivated with plows; otherwise we might plow too deep and destroy many roots. At one of the agricultural experiment stations it was found that thirty days after planting corn, at the second



Fig. 32. The root development of a corn plant just beginning to tassel. From Photo made at Agricultural Experiment Station, University of Illinois.

cultivation, the roots from the adjacent hills (three feet apart) had already met. A few roots had reached a depth of twelve inches, but the bulk of the roots were within eight inches of the surface. Six inches from the hill, the main roots were within two or three inches of the surface. Midway between the drills they lay within four inches of the surface. Deep plowing at this time with shovel-pointed plows would certainly have injured many roots.

82. The Condition of the Soil has great influence on the distribution of the roots. Where the surface layers are moist the roots will grow freely in these layers, but if dry spells come the plants will suffer more than plants that have been growing on soils less favorably supplied with moisture. This explains why it is best, in watering lawns, to give them a heavy drenching rather than a frequent sprinkling of the surface, so that the water will soak down into the deeper layers.

83. Grass-like Plants are without tap-roots. They form a number of fine roots near the surface, and are hence known as "surface feeders." Other plants, like cotton, alfalfa, peanuts and beans, have strong tap-roots that branch out in the lower layers of soil, and are for this reason called "deep feeders." We must not conclude from this that the small grains do not have deep-feeding roots. Notwithstanding the small diameter of the root branches, some of them penetrate the soil much below the surface layers, as illustrated in Fig. 32.

QUESTIONS

1. What conditions of open-field culture are under our control?
2. What are the uses of soil to a plant?
3. What kinds of roots grow in moist, fertile soils?
4. What kind in poor soil?
5. What is an ideal soil for plants?
6. What conditions of soil particles prevent the right supply of food?
7. What are the three general ways of changing the texture of the soil?
8. When is a soil in good tilth?
9. Why is it necessary for a plant to have a large root surface?
10. What is the general rule as to the distribution of roots?
11. What is the effect of moisture on the downward distribution of roots?
12. Shall crops be tilled deep or shallow? Discuss this question.
13. Why are the grasses called surface feeders?
14. Explain how deep breaking of the soil makes a larger and better home for the roots.

CHAPTER X

SOILS AND SOIL MANAGEMENT

84. From what we have learned, we recognize that the proper management of soils should be such as to:

(a) Provide the plant with an adequate supply of available soil moisture at all times.

(b) Put the soil in such tilth that the roots can find abundant supplies of the important soil nutrients.

(c) Provide for the removal of the surplus water (drainage) that would fill up the air spaces and prevent the proper development of the roots.

(d) Make the soil sufficiently loose so that the oxygen of the air and the water in the soil may circulate freely.

85. Classification of Soils. Before we can intelligently discuss the problems of soil management we should learn more about the properties of the different kinds of soils. By "soil" we mean that layer of the earth's crust which is formed from finely broken-up rocks and decayed plants and animal remains. Soils are variously classified according to origin*, method of formation, chemical composition, physical properties, or adaptations to kinds of crops. It will be advisable for us first to learn more of the properties of the substances that compose the various kinds of soils.

86. Origin of Soils. The geologist classifies soils according to their origin and conditions of formation. He tells us that all soils have been formed by the gradual breaking up of rocks. Fig. 33 shows a mountain of rock

*See chapters on Erosion in any text-book on geology or physical geography.

being slowly but surely converted into soil. The large boulders break and fall from the cliffs, and by the weathering of the rains, frosts and other agencies, they are worn away. The finer particles are washed down the hillsides into the valley below, forming the rich valley soil. Soils formed in this way by the deposit of the sediment from running water are called *sedimentary* soils. In some cases the rocks break up and are not



Fig. 33. Soil formation. Rain, frost and plants all assist in changing the mountains of rock into soil. After Hill. United States Geological Survey.

removed by flowing water. Such soils are referred to as *residual* soils.

86a. Weigh a fruit jar and fill with the muddy water flowing from the field after a heavy rain. Let stand until the water is clear, and note the amount of soil in the bottom of the jar.

86b. Weigh the jar again, pour off the clear water, leaving the thick sediment. Dry and weigh the sediment, and calculate the per cent of sediment in the muddy water.

87. Other Classifications. A convenient and natural classification of soils is often made according to the color, texture and structure of the soil layers. We commonly speak of a soil as consisting of a *surface soil* and a *subsoil*.

The surface soil includes the top layer of soil—"that which is moistened by the rains, warmed by the sun, permeated by the atmosphere, in which the plant extends its roots, gathers its soil-food, and which, by the decay of the subterranean organs of vegetation, acquires a content of humus." The surface soil may be subdivided further into surface soil and sub-surface soil; the surface soil proper, or soil mulch, includes the layer of top soil that is moved about by the ordinary operations of tillage; and the sub-surface soil refers to the layer of surface soil that is just beneath the soil mulch, thus being a part of the surface soil and yet is not stirred by ordinary inter-tillage.

The subsoil is the layer just below the surface soil, and in all soils it is taken to mean the second layer, showing characteristic differences from the surface soil. Sometimes the subsoil, or a layer just beneath the top layer of the subsoil, may consist of a hard, stiff layer of clay or other compacted material, impermeable to water and air. This is spoken of as *hard-pan*. It is often absent altogether, or it may be at various depths. It

may be considered as a condition of the subsoil rather than as a different material, where it is composed of the same material as the subsoil.

88. Sand. Sand is broken-up fragments of a mineral called quartz, or flint. It often occurs mixed with considerable quantities of coarse gravel. Pure white sand is almost valueless for agricultural purposes, because it supplies no needed mineral element. However, it rarely occurs pure, but mixed with other minerals that supply plant food. Sandy soils are usually classed as "light" soils because of the light draft in plowing. They are in reality very heavy, for a cubic foot of air-dry sand will weigh over a hundred pounds, whereas an equal quantity of clay will weigh only about eighty pounds. The grains of sand are rounded, and so there are spaces between them. This allows water and gases to move easily through sandy soils. Because of their open nature, sandy soils readily take in large quantities of water. For the same reason, they allow it to drain off or evaporate quickly. Sandy soils are usually drier and better aerated, and will, for this reason, warm up sooner than other soils and are, hence, preferred for growing early vegetables.

89. Clay, in an agricultural sense, includes any soil composed largely of very fine particles, which gives the land a close, compact, adhesive nature. Clay, as used by chemists and potters, refers to the disintegrated mass of certain kinds of rocks. The several kinds of clay soils vary widely in chemical composition, physical properties, and fertility. Usually, however, clay soils are very productive. Clay has the property of absorbing large quantities of water, often as much as from 50 to 75 per cent of its own weight. Even the dry clay road

dust may have as much as 10 per cent of water. When wet, clays become sticky and impervious to water and air, and, of course, root growth cannot take place when the soil is in this condition. If kneaded or puddled by working at this time, it does not crumble on drying. Clay particles have a tendency to cling together in small lumps, or floccules, especially if lime is present. This makes them more open and porous, and lightens the draft in plowing. Water evaporates slowly from clay soils.*

90. Calcareous, or Limy Soils. Many fertile soils contain large quantities of crumbled limestone (carbonate of calcium). The presence of lime in a soil may be easily detected by the effervescence (giving off of gas) when treated with acids. Strong vinegar will answer. Try it on some lumps of soil. Finely pulverized limestone has physical properties similar to clay. Lime tends to improve clay soils by making them more granular and porous. Lime also acts beneficially on sandy soils by increasing their water-holding power. The fertile black lands of Texas contain from 5 to 40 per cent of carbonate of lime. Soils low in lime often become sour or acid, (§ 141.)

90a. Effect of Lime on Clay Soils. Take about three pounds of stiff clay soil and work into a soft plastic mass by wetting and kneading. Divide into three equal parts. Round one into a ball and put on a board. Work the second up with an equal volume of air-slaked lime, and the third with half as much air-slaked lime. Put all three on a board and let dry. Describe the results. What is the effect of the lime on clay soils?

90b. Effect of Lime on Clay Particles. Clay settles slowly in water. The particles are so fine that they float in water like dust in the air. Rub up some clay in water until the water is turbid. Pour a little

*Are the clay soils of your community classed as drought-resistant soils?

of this turbid water into lime water.* What happens to the particles of clay suspended in the water?

91. Humus is the term applied to partly decayed plant and animal remains, and is well illustrated by the leaf-mold found under the trees in a dense forest. Humus gives to the soil a characteristic blackish color, and adds greatly to its fertility. It improves the water-holding power in a noticeable degree, often to double the original water-storing power. It makes clay soils mellow and sandy soils compact. Humus is formed by the decay of the roots, leaves, etc., in virgin soils. The farmer is able to increase the humus in the soil by adding compost directly, and by plowing under straw and green crops, like cow-peas, etc. (See ¶ 131, Green Manuring.)

92. Examination of Soils.† An experimental study of the several kinds of soils, especially of those occurring in the school district, should be made, and, if a sufficient number of different kinds are not close at hand, others may be secured. These various kinds of soil consist of mixtures of varying amounts of sand, clay, limestone dust, and half-decayed plant remains. The fertility and water-holding power will bear some relation to the amounts of these separate substances composing the soil.

*To prepare lime water, secure a large-mouthed bottle or fruit jar. Fill half-full with water. Add lime, a little at a time, until a good handful is used. Cork securely, to keep out the air, and let stand. The lime will settle to the bottom and the clear liquid above is lime water.

†The direct examination of the samples of soil, as outlined in this chapter, may be conducted by any boy or girl with little or no assistance from the teacher. A word of caution may be given to the student. He should be reasonably familiar with the theory of the work he is to undertake, and what questions his results may answer. Too often he will want to say that he is "going to prove" so and so. He should be cautioned to "find out" if so and so is *true* or *not true*. This is the attitude of the true student.

93. Size of Soil Particles. In recent studies on American soils, much attention has been given to the determination of the size of the particles in good agricultural soils. Fig. 34

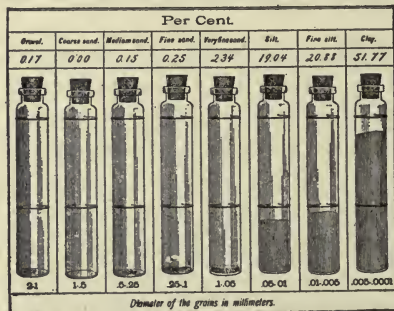
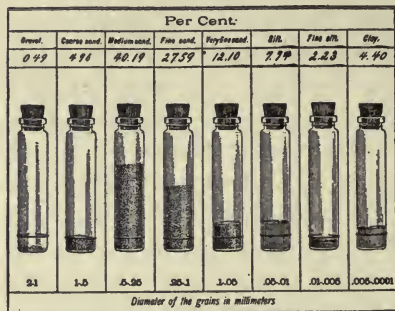


Fig. 34. Showing the amounts of the particles of different size in two kinds of soils. From Bureau of Soils, United States Department of Agriculture.

shows how two soils may differ in this respect. In noting the size of the soil particles, we should distinguish between the actual size of the minute particles or fragments of rocks and the soil floccules, or granules formed by the sticking together of a number of very small particles.

93a. Examination to Observe the Size of the Soil Granules. Secure a half-dozen lumps of soil from the moist layers beneath the surface, and put into a fruit jar three-fourths full of water. Screw on the top and shake vigorously for some minutes, and allow

to settle. Describe the layers formed after standing one hour or more. Note the differences in size of the granules of the soil. Apply the same treatment to a handful of garden soil; to a sample of stiff clay soil.

93b. Secure a good handful of soil and moisten and work till a very thin, even paste is formed. Place in a jar. as in ¶ 92a, and shake. Allow to stand until the particles have all settled to the bot-

tom. Observe the different layers. The coarse material at the bottom is probably sand. Above this will be a layer of finer particles consisting largely of clay, the finest particles of which remain in suspension in the water, making it turbid. Small particles of vegetable matter may be found floating on the surface. The separation of the particles will be more complete if a small quantity of ammonia be added to the water.

Estimate the amount of sand and clay in the samples. What effect did working the soil into a paste have on the size of the granules?

Make similar tests with a number of different kinds of soils. Make a table as shown below, and record your observation for each sample of soil.

93c. Classify the soils examined according to the following scheme. Estimate the amounts of the sand or clay.

Kind of soil	Per cent of sand present	Color of fresh soil	Productive or unproductive	Drought resistant or not	Heavy or light draft	Remarks
Sandy	80-100					
Sandy loam..	60- 80					
Loam	40- 60					
Clay loam....	20- 40					
Clay.....	0- 20					

93d. Weight of a Cubic Foot of Soil. It will not be necessary to use a full cubic foot. Small, rectangular boxes may be made and then carefully measured for their inside dimensions. The dirt may be put in these and weighed, and the results calculated to a cubic foot. Three-pound tomato cans, with the tops melted off, may be used in the same way. The samples of soils should be thoroughly dry and free from coarse lumps. A sample of every type of soils in the community should be used.

94. Temperature of Soils. Soils have the power of absorbing the heat from the sun's rays. If they absorb the heat readily they are called warm soils, and if slowly, cold soils. Dry soils get warm much more quickly than moist soils. Barefooted boys know that the dry sands and fine clay road dust become warm more quickly than moist soils.

The amount of water in the soil affects the temperature more than the kind of soil. Much heat is required to warm and dry out wet soils. Most of the heat is consumed in evaporating the water. The evaporation of water from the soil may be compared to the evaporation of sweat from the body, because it cools the soil, just as evaporation cools the body.

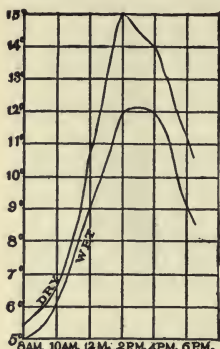


Fig. 35. Temperature curves of dry and wet soils.

The texture of the soil also affects the temperature. Coarse rocky or lumpy soils suffer from sudden changes in temperature. Loose and well-cultivated soils absorb and retain the sun's heat

best; and the temperature in such soils is more uniform.

The color of the soil affects the amount of heat absorbed from the sun's rays. Dark-colored bodies absorb the heat rays more readily than light ones. This explains why dark soils are warmer than light soils.

While a compact soil will absorb heat more rapidly from the sun's rays than a loose one, it will also lose heat more quickly, because of the more rapid conduction of the heat to the surface, where it is lost by radiation.

Moist soils warm up more slowly than dry ones, because the heat is used up in warming and evaporating the water. (Fig. 35.)

94a. Absorption of Heat from the Sun by Dry Soils. Air-dry soils should be put into uniform vessels. Gardeners' flats are quite suitable. Insert ordinary dairy thermometers into the soil for about two inches and note the temperature in each box. Put the box in strong sunlight and make readings at 8, 10, 12, 2, 4, and 6 o'clock. Record the temperature as shown in Fig. 35.

94b. Rate of Cooling of Dry Soils. The same boxes used in ¶ 93a may be used. Note readings when placed in sunlight at 8, 10, and 12. Then put in shade and note the temperature at 2, 4, and 6. Which kind of soil cooled quickest? What soils retained their heat longer? Do the soils that warm quickly cool quickly? What soils would you class as "warm soils?"

94c. Absorption of Heat by Moist Soils. Use same boxes of soils as above, but add same amount of water to each, and make readings when exposed to sunlight from 8 until 4. The cans or boxes should be weighed at the beginning, and, when through with the test in this experiment, weighed again for results in ¶ 95a, noting loss of weight in each.

94d. Loss of Heat by Moist Soils. As above in ¶ 94b. The same boxes may be used.

95. Soil Mulch. The rain falling on the surface causes the many fine lumps of soil to crumble and run together, and leaves the surface covered by a closely compacted layer or crust. This condition of the soil is very favorable for the rapid evaporation of the capillary water. When the surface becomes dry, the water below will move rapidly to the surface and the soil will soon become dry. The thrifty farmer destroys this crust just as soon as the surface layer can be harrowed or plowed. He thus destroys the close capillary connection formed between the surface and sub-surface soil. The soil mulch should be two or three inches thick. (Fig. 36.)

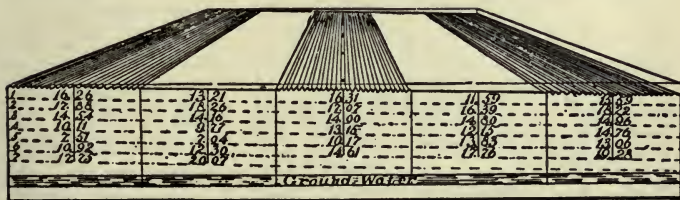


Fig. 36. How cultivation retards surface evaporation. The position of ground water after fifty-nine days, and the per cent of water in the soil at different depths. The shaded plots were cultivated. After King. University of Wisconsin.

95a. Rate of Loss of Water. Use three-pound tomato cans. Put equal volume of air-dry soil of different kinds in each, and add same amount of water to each. At 4 o'clock each day, note the amount of water lost from each kind of soil during four separate days, and calculate the per cent of total water lost for each day. Record the results as shown in the following table:

	Weight at beginning	End of first day	End of second day	End of third day	End of fourth day	Per cent
Sandy soil						
Clay soil						
Garden soil						
Coarse gravel						

95b. Rate of Rise of Water Through Soils of Different Texture. For this test, a number of ordinary lamp chimneys serve very well, because the results may be easily observed. These may be secured at stores. Select three samples of soil: one sand, one clay, and one a soil with much humus. Prepare two chimneys of each kind of soil, as follows: Close the tops of the chimneys with muslin. In number one, let the soil particles drop lightly into the chimney and remain very loose. In number two, pour in a little at a time and press slightly

with a stick. Do not try to make too compact, lest the chimney be broken. Put all the chimneys in a vessel of water, as shown in Fig. 37, and note the rise of the moisture every recess hour.

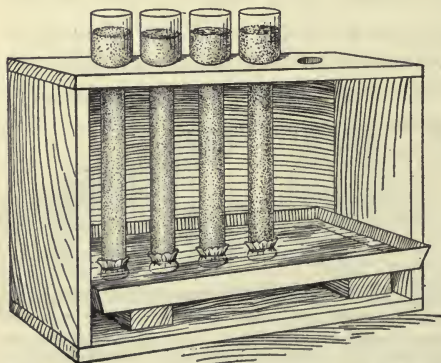


Fig. 37. To test the rise of water through soils of different texture.

What effect does compacting the soils have on the quickness with which they absorb water in sand? In clay? In humus?

95c. Effect of Mulches on Evaporation of Water from Soils.

Secure seven or eight three-pound tomato cans from which the tops have been carefully melted off to leave smooth rims. Fill three of the cans full to the upper edge with clean, dry sand or other soil. Fill the remaining ones within one inch of the top. Weigh the cans separately when dry, and add the same amount of water to each one and note the weight. Prepare the mulches as indicated below, and weigh again. Set in a convenient place

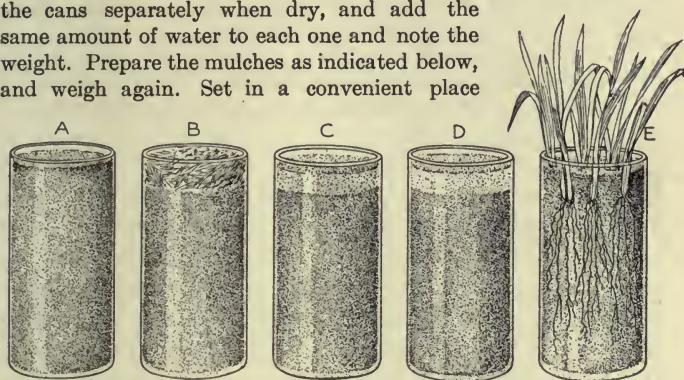


Fig. 38. Consuming soil moisture. Loss in seven days: *A*, packed surface, 8½ oz. water; *B*, fine chopped straw, 2 oz. water; *C*, covered with loose sand, 1 oz. water; *D*, dust mulch, 3 oz. water; *E*, young oat plants, 10 oz. water.

where they will all be exposed to the same conditions. Weigh daily for one week or ten days, and record the loss of weight for each can on the following table. The difference in loss will approximate the power of these separate mulches to retard evaporation from the surface. Give all the cans the same exposure to light and wind.

EFFECT OF MULCHES ON EVAPORATION

No. of can	First day		Second day		Third day	
	Weight	Loss of weight	Weight	Loss of weight	Weight	Loss of weight
1						
2						
3						
4						
5						
6						
7						

1. Not mulched. (Check or control.)
2. Surface cultivated one inch deep (soil mulch).
3. Surface cultivated two inches deep (soil mulch).
4. Mulch with one inch of coarse gravel.
5. Mulch with one inch of sawdust.
6. Mulch with one inch of fine sand.
7. Mulch with one inch of fine cut straw.

Which mulch is most effective?

Which mulch is most practical under field conditions?

What other conditions affect evaporation from the soil?

96. Soil Moisture Retained by Cultivation. Professor King has investigated the efficiency of surface cultivation in retaining water in the soil. A piece of fallow ground was divided into plots twelve feet wide, as shown in diagram in Fig. 36. Three were cultivated and two left fallow. The figures in the table show the percentage of water in the soil of each plot, at different depths, at the end of fifty-nine days. The average loss of water from the cultivated plots was 709.4 tons per acre, while in the non-cultivated plots the loss was 862.3 tons per acre. This makes the mean daily loss of water from the ground not cultivated 3.12 tons per acre greater than was that from the cultivated soil. This cultivation saved the equivalent of 7.9 inches rainfall. The soil mulch is a great protection against temporary drought. It saves the soil water for the plant to use in making food; whereas, if allowed to evaporate from the surface of the soil, it would be lost. The mulch should be renewed after every rain. It seems strange, but it is true, that a summer shower will destroy the mulch, and cause the land to dry out so much faster that the soil will contain less moisture after a few days than if it had not rained at all. Such a shower moistens only the surface, destroying the capillary spaces between the soil particles.

97. "Dry-land Farming." In some sections of the country where the rainfall is so light that the trees and, other large plants requiring large amounts of water, will not grow, the soil mulch has been found to be an excellent conserver of soil moisture. A crop is grown only every other year. The fields are divided into two parts. One is planted in grain, and the other will be harrowed after each rain, or oftener, to form a mulch. In this way, the water is stored up one season for the next season's crop, and from twenty-five to fifty bushels of grain to the acre are harvested every other year. If a crop were grown every year on all the land, the yield would not average ten bushels per acre.

98. How Plants Dry the Soil. Do plants take moisture from the soil faster than ordinary evaporation? To get an answer to this question, fill four tomato cans with a good garden loam. In one plant nothing; in another, forty or fifty grains of oats; in another, five or six grains of corn. Put an elder stem or hollow cane on the side of each so that the plants can be watered from the bottom. If we put water on the surface, a crust will form that will cause the water to evaporate much faster. (Do any of our experiments justify this statement?) Pour just enough water down the tube to make the soil reasonably moist, but not too wet. Set in a warm place, and, when the seedlings are half an inch high, weigh the cans and determine the loss of moisture in the usual way. Keep the cans in a place where the plants can get a good light, but not where the sun would heat the earth too much. Sum up your results at the end of the first week, and answer the questions given above. Likewise, at the end of the second week. Can you explain the bad effects of weeds in dry times.

99. Absorptive Power of Soils. Soils have the power of absorbing many substances, particularly some that are valuable plant foods. Prepare two lamp chimneys as described in ¶ 95b, and fill with good field or garden soil. Into one pour several ounces of water made deep blue with laundry blueing. Note the color of the water when it comes through the cloth below. Into the second chimney pour foul water made by leaching compost. Coloring matters or soluble salts like fertilizers, absorbed in this way (physical absorption), are merely held more firmly to the surface of the soil particles, so that they are not readily leached out by percolating waters. Mineral plant foods held in the soil in this way are available for absorption by the roots of plants.

Wood ashes contain the salts left from the plant when the air-derived substances have been driven off by burning. It represents the valuable salts absorbed from the soil. Take some home-made lye and taste a drop on the end of a broom straw. Allow to filter through the soil as above and try the taste of the drippings. Has the soil absorbed any of the salts?

QUESTIONS

1. What are the ends to be worked for in soil management?
2. What is meant by "soil?" How does a geologist classify soils?
4. What is the farmer's classification of the layers of soils? 5. Name the four chief components of soils. 6. What are the advantages and disadvantages of a sandy soil? 7. Of a clay soil? 8. Of a limy soil? 9. Of humus in soils? 10. What is the importance of the size of soil particles? 11. What do you understand by soil particles, and soil granules? 12. What does the farmer mean by heavy and light soils? 13. What kind of soil warms up most quickly? 14. Why does the farmer harrow or plow up the crust formed by rains? 15. What is meant by dry-land farming? What is its advantage? Explain.

CHAPTER XI

WATER IN THE SOIL

100. How the Water Exists in the Soil. From our experiments, we have noticed that the water in the soil may be classed as:

(a) *Free, or gravitational water*, the water which flows under the influence of gravity and percolates downward. When the water collects below, we call it bottom, or ground, water, and the surface layer is called the *water table*. (See Figs. 36 and 41.)

(b) *Capillary water* is held in the capillary spaces or pores of the soil and is not influenced by gravity, but moves upward, or in any direction where the soil is becoming drier. It is held in the soil by the same force which causes the whole of a rag to become wet when one end is placed in water, or which causes oil to rise in the wick of a lamp. The amount of capillary water, that is, the water which the soil may retain against the influence of gravity, depends on the size and form of the soil particles, and several other conditions. Where there is only capillary water in the soil, there is, of course, some



Fig. 39. Diagram to illustrate how the soil particles are covered by capillary water. After Cameron.

air space, because the capillary films will not be thick enough to fill the spaces between the grains, especially if the soil is coarse grained. This is the condition most favorable to the growth of roots, because both water and air are present. (Fig. 39.)

(c) *Hygroscopic water* is the film of water held on the surface of solid particles independent of capillary spaces. It is held more firmly to the grains than capillary water. Air-dry soil may still contain from one to ten per cent of hygroscopic water,—that is, water which may be driven off only by heating to the temperature of boiling. Clay soils, in particular, often contain large amounts of hygroscopic moisture.

100a. Rate of Percolation of Water Through Soils. Prepare lamp chimneys as in ¶ 95b, filling them two-thirds full, using different kinds of soil. Quickly fill all the chimneys full to the top with water, and then notice the time required for water to begin dripping at the lower end. It will be well to place wide-mouthed bottles under each chimney to collect the drippings. In this way the amount of water percolating through the different soils may be estimated. Which would be preferable in field conditions, for the water to percolate rapidly or slowly? Discuss this question.

Soil	Time required for first flow from bottom of chimney	Amount of water passed through chimney at end of		
		First day	Second day	Third day
1				
2				
3				

101. The Amount of Capillary Water which a soil may retain varies with the soil. This is a measure of the power of a soil to store up water. The following table, taken from Schubler*, who first investigated this property

*See Johnson, How Crops Feed.

of soils, shows that sandy soils retain water poorly and that humus may retain nearly double its weight in water.

	Maximum capillary water	Water lost in four hours
	Per cent	Per cent
Pure sand	25	88.4
Lime sand	29	75.9
Clay soil (60% clay)	40	52.0
Loam	51	47.5
Heavy clay (80% clay) ...	61	34.9
Pure gray clay	70	31.9
Fine carbonate of lime	85	28.0
Garden mold	89	24.3
Humus	181	25.5

The second column shows the percentage of water that evaporated in four hours, when spread over a given surface. It is seen that soils having capacity for large amounts of capillary water part with it very slowly.

102. What amount of water is most favorable to the growth of plants? This has been experimentally studied by Hellriegel, who found that oats, wheat, and rye growing in sand able to hold twenty-five per cent capillary water made maximum yield with fifteen to twenty per cent water. He observed that the plants would grow with no less vigor when the soil contained even only 2.5 per cent water. Below this the plants would wilt. It is not generally true that the most favorable amount of moisture for the growth of a plant is the full capillary power of the soil, as might be inferred from the above results. The results of some investigations of the United States Department of Agriculture show that plants might suffer for lack of water (drought limit) when the soil contained 15 per cent moisture, while in other soils the plants were well supplied.

when the soil contained only 4 per cent moisture. In some soils 20 per cent moisture caused injury, while in others only 10 per cent moisture acted injuriously on the plants. These figures indicate approximate amounts only. While the range from the "dry" to "wet" seems narrow, it should be remembered that 1 per cent difference in water in the first foot of soil would amount to a rainfall of only about 0.41 inch for clay soil and 0.57 inch for sand, allowing 80 pounds per cubic foot for clay soil and 110 pounds for sand. Water weighs 62.31 pounds per cubic foot. One inch of rainfall completely absorbed would increase the percentage of moisture about six per cent.

103. In Irrigation it is important to know how much water to apply. Injury may be done by applying too much water, besides causing undue expense in handling the water.

103a. How much water should be applied to a sandy loam soil weighing 90 pounds per cubic foot to raise the moisture from 3% to 20%?

104. What Becomes of the Rain? The average annual rainfall at Washington, D. C., is about forty-four inches; that is, in a year's time, the rain, snow, and sleet would be sufficient to cover the surface forty-four inches deep in water. In some parts of the United States the rainfall is fifty inches, and in other sections only about fifteen. What becomes of this large amount of water? Some of it runs off into the creeks before it can be absorbed by the soil. This is called the "surface run-off," or simply surface water. This water is lost for the use of the plants. When the surface layers are hard and compact, the water can not be absorbed quickly, and may even flow off while the roots in the deeper layers are

suffering from a lack of moisture. If the fields were kept well plowed, more of this water would soak into the soil and could later be used by the plants when dry times come. If more water soaks into the layer of tilled soil than it can retain by its capillary properties, it is absorbed by the sub-soil and may finally percolate down to the layer of rock or clay and flow off to form springs. It is much better for the farmer if the surface soil and the sub-soil are well supplied with water. The rains are usually not abundant in the season when they would be most beneficial in increasing the yield of the

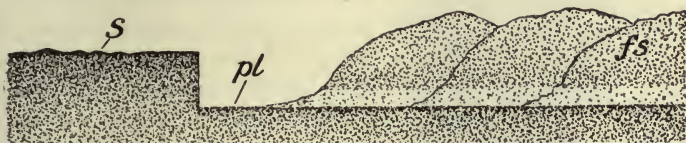


Fig. 40. Diagram to illustrate the effect of ideal plowing. The compactness of the soil is indicated by the density of the shading. Before plowing, there is a compact surface crust (*s*), below which the soil grows less compact as we go deeper; after plowing, this compact mass is broken up into a loose, friable mass of soil-crums, or floccules, with a consequent increase in the bulk of the furrow-slice (*fs*); compacted plow sole at *pl*. After Hilgard.

crops. This fact suggests all the more strongly the importance of studying the ways that may be used to:

1. Increase the ready absorption of the rainfall;
2. Increase the water-storage power of the soil occupied by the roots (§ 100);
3. Increase the efficiency of mulches in conserving the moisture for the use of the crops;
4. Prevent injury to the fields by surface washing.

105. The Water-Storage Power of the soil may be increased in two ways: (a) *By deep breaking*. This increases the pore space in the soil by making the granules of soil smaller. They, therefore, have more capillary space (§ 75). Breaking should be done in the fall so that

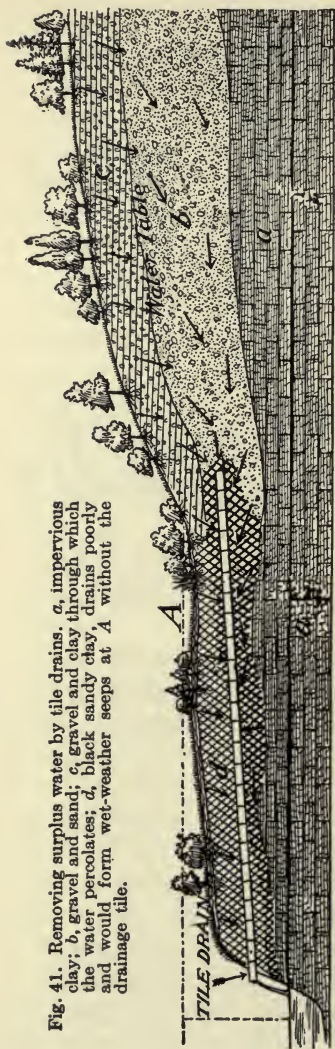


Fig. 41. Removing surplus water by tile drains. *a*, impervious clay; *b*, gravel and sand; *c*, gravel and clay through which the water percolates; *d*, black sandy clay, drains poorly and would form wet-weather seeps at *A* without the drainage tile.

the winter rains may be absorbed. (b) *By adding substances to the soil that increase its water-holding power, such as compost and green manures* (§ 101). Increasing the water-storage power of the soil tends to lessen washing. The water “runs” after every little shower in the hard roadway, but in the well-plowed field the rain is soon absorbed and passes to the deeper layers of soil. A well-plowed field may absorb a full three-inch rainfall, and thus lessen the damage so often caused by surface washing. No one may say when the rains will come, nor forecast the amount; but the farmer has it in his power to store up a large amount of the rain to provide against temporary drought. This he may do by increasing the storage space by deep fall plowing, which prepares the ground to readily absorb the rain. The evaporation may be reduced by renewing the soil-mulch after each shower. This is particularly important in regions of low rainfall.

106. Amount of Water Required to Mature a Crop. For every pound of dry matter made by growing corn, cotton, oats, etc., it has been estimated from many experiments that from two hundred to four hundred pounds of water are required. This includes the entire plant above ground, regardless of that which is harvested. Accepting these figures as nearly correct, let us estimate how much of the rainfall is consumed in maturing a good crop of corn, cotton, oats, etc. In a field of corn making fifty bushels per acre the figures would be roughly as follows:

50 bushels corn (72 pounds to bushel) . . .	3,600	pounds
Stalks and leaves	3,600	"
Plant substance	7,200	"
Approximate quantity of water required for each pound of plant substance . . .	300	"
Water used by crop	2,160,000	"

A cubic foot of water weighs 62.3 pounds. A rain-fall of one inch would be 5.19 pounds per square foot of soil, or $43,560 \times 5.19 = 226,176.40$ pounds on an acre. Dividing 2,160,000 by 226,176.40, we find that less than ten inches of rainfall would be used by the plants in making fifty bushels of corn per acre. This does not include the water that would evaporate from the soil or be lost by the surface run-off.

106a. At Kansas City, Mo., the average annual rainfall is about 38 inches. What per cent of this would be required to make 50 bushels of corn per acre? What is the average rainfall in your county? See Appendix H.

107. Soil Drainage. There are many places in low bottom lands on which water accumulates to an injurious extent, either from seepage from the hills or from the lack of an outlet for the surplus water in very wet spells. Again, there are low "sweeps," "swags," "runs,"

“sloughs,” and the like, in which water stagnates to the detriment of the soil and the crops. Such places may often be greatly improved by making surface ditches or by placing drainage tiles (Fig. 41) to carry off the surplus water. In making open ditches it is better, if circumstances allow, to make them broad with sides sloping up about one foot in three or four. This will permit of the cultivation of the drainage-way, and leave no banks to harbor weeds or interfere with the driving of the plows in any direction. Sometimes underground drainage ways are provided. These are often made by digging narrow ditches to the proper depth and filling partly with coarse stones, logs, etc., before refilling. The surplus water finds an outlet through the spaces between the stones. Regular drainage tiles are now most often used in place of loose stone. They may be secured in any size to suit the local conditions. Many fields have been greatly improved by placing rows of tile drains every thirty feet or so. The prompt drainage of some soils is just as important as the conservation of water in others. An excess of water delays the warming of the soil in spring, and prevents the growth of the roots.

On hillsides, water flows off so quickly that it forms washes, or gullies, in the land. The field is injured, not only by a direct washing off of the productive surface soil, but also by a leaching out of the valuable mineral plant foods that accumulate in the surface soils that are not washed. (§ 130.) Every one has noticed the lessened productiveness of sloping hillsides that have been long in cultivation. Many plans have been proposed to lessen these losses to the productive qualities of such lands, or to restore such qualities to fields that have been injured by neglect. Some lands wash badly, even though the

slope is very gradual. Uncultivated lands are protected from devastating washings by their coverings of grass, weeds, and other forms of vegetation. The latter retard the flow of the surface water, and therefore allow more of it to soak into the soil.

In preventing injury by too rapid surface drainage, or in recovering land that has been injured by washings, several working principles have been proposed, which may be applied with success, either singly or in combinations, to suit the local circumstances:

(a) *By Terracing*. This consists in breaking the slope up into a number of terraces, or level belts, with sharply sloping sides, such as may be observed on a very large scale along the shores of lakes or water courses. The terraces are made nearly level, so that the rain is kept on the land longer, and therefore facilitates absorption and allows the excess to flow off slowly. Terraces are preferable to the old-time hillside ditches. The latter quite often magnify the trouble they were intended to prevent. Objections are made to terracing because of the great cost of construction and the increased cost of cultivation. Also, because a part of the land is left uncultivated, and therefore likely to grow up in weeds. The practice of running the rows on a level around a hillside may be considered a form of terracing.

(b) *By Deep Breaking*, or keeping the absorptive power of the soil to a point where moderate rains will be readily absorbed. (§ 105.)

(c) *By Growing Cover-crops* (§ 144) which not only protect the land while they are on the land, but also add vegetable matter which tends to bind the soil together. Soils in southern climates usually contain less vegetable matter, and therefore suffer more from wash-



Fig. 41b. Growth of rye in early spring. *A*, unfertilized; *B*, fertilized with nitrogenous fertilizer. The leaching rains had robbed the soil of its natural store of nitrogen. Arkansas Experiment Station.

ing than similar soils in northern climates. This fact should suggest to farmers in southern climates their need of greater attention to the use of cover crops. (Fig. 41b.)

QUESTIONS

1. In what three forms does water exist in the soil? 2. Explain capillary water. Hygroscopic water. 3. Between what per cents of water content do plants grow most vigorously? 4. Can an irrigated field have too much water? 5. What becomes of the rains? 6. What can the farmer do to make use of a greater amount of the average rainfall? 7. About how much water is used for every pound of dry matter made by growing cotton, or corn? 8. Why is soil drainage important? 9. How should open drains be made? 10. What is a tile drain? 11. Why are foot-hill fields more productive than hill fields? 12. Mention several ways of reducing the leaching and washing of hillside fields. 13. Explain the theory of each method.

CHAPTER XII

RELATION OF THE PLANT TO THE CHEMICAL COMPOSITION OF THE SOIL

"The soil is not only a sponge, from which the plant may obtain water, but it is also a storehouse of plant food and a laboratory in which the plant food is prepared and dissolved for the plant."—Osterhout, Experiments with Plants.

108. In the preceding chapter, the relation of the plant to the water contained in the soil, and the means by which the water supply may be increased, have been discussed. These tillage operations not only cause the water to be retained for the use of the plants, but to dissolve the mineral food elements in the soil. While the amount, the kind, and the condition of these soil foods affect very greatly the fertility or agricultural value of a soil, we should remember that, without resort to means for improving the mechanical condition, many soils, naturally rich in plant food, would yield poor crops. We should therefore not only study closely the relation of the chemical composition but of the physical properties of the soil to the fruitfulness of the crops.

109. The Essential Elements. By growing plants with their roots in a medium of known composition, plant physiologists have determined which elements of the soil are really necessary for the healthy, normal growth of the plant. By the same means they have been able to determine the effect of other substances. For these tests, the plants are usually grown in vessels thoroughly

cleaned and partly filled with distilled water (water cultures), or with pure sand (sand cultures), to which are added solutions containing the different substances supposed to be necessary for plants. These solutions are made similar in every respect to the solutions as they occur naturally in the soil. Plants have been grown to maturity in these artificial solutions side by side with

ones just like them planted in the ground, and with equally satisfactory results. Where it was desired to determine if, say, potassium was really necessary, a solution was prepared having all the ingredients found in the soil waters except potassium, and in this the plants would be grown. Fig. 42 shows the results of growing buckwheat in a complete or normal nutrient solution and also when certain important elements are withheld. It should be remembered that some potash, calcium, etc., was in the seed

so that not all the mineral nutrients are kept from the plantlet. Sodium, while quite similar to potassium, can not replace potassium as a nutrient.

110. Effect of Fertilizers. Another way of testing the effect of a substance is to grow the plants in some

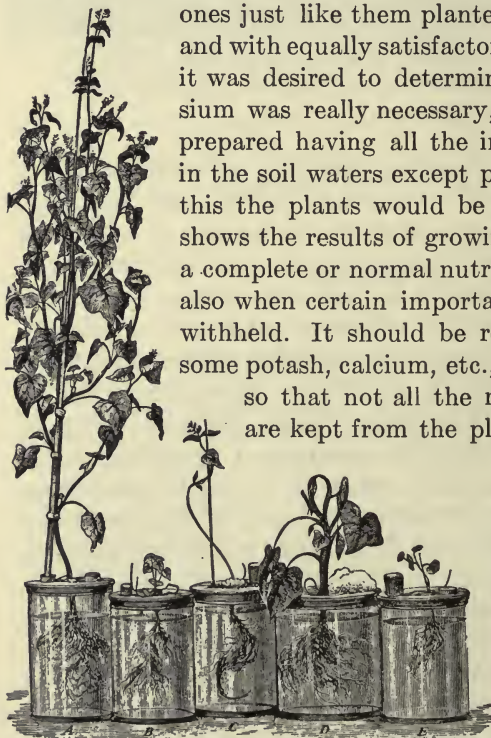


Fig. 42. Buckwheat grown in artificial solutions of mineral nutrients. A, complete solution; B, potassium withheld; C, nitrogen withheld; D, calcium (lime) withheld; E, without potassium, but sodium added. Drawn from photograph by Nobbe.

available soil and *add* the substances to the soil. This is called fertilizing the soil. Fig. 43 illustrates the effect of applying different fertilizing substances to a sandy soil taken from a field in Eastern Texas. Fig. 44 shows the effect of adding nitrogen, potassium and phosphorus to pot-cultures of alfalfa made at the Oklahoma Agricultural and Mechanical College.

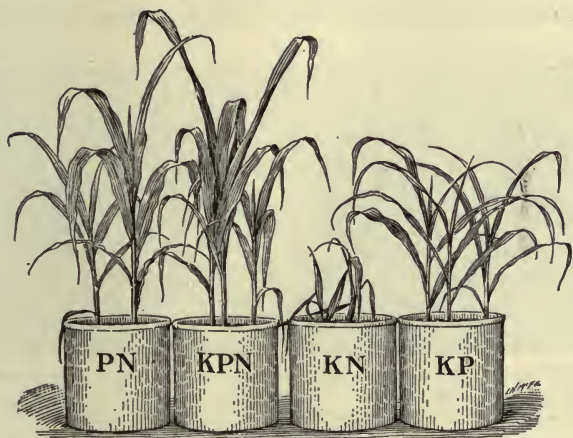


Fig. 43. Effect of fertilizers on fine sandy loam. An application of phosphoric acid is denoted by P; potash by K; nitrogen by N.

111. The Quantity of Fertilizing Substances added to the soil is but a small fraction of the increased weight of the crop which it produces. Minerals are absorbed by the plants in exceedingly small amounts, for they form only about one part in two hundred of the fresh, living plant, and rarely more than five per cent of the dry substance. They are necessary as food substance; they become a part of the living plant substance. Exceedingly small amounts suffice in the case of iron, sulphur, chlo-

rine, calcium, and magnesium. The substances named occur in nearly all soils in quantities sufficient to supply the plants abundantly. Other substances, as potassium, phosphorus and nitrogen, are more important, and must be supplied when necessary. (See table of fertilizing substances in feed-stuffs in Appendix.)

112. The Form in Which Plants Take Up Their Mineral Food. These "elements" occur in the soil as compounds with other substances. The soil is composed mostly of



Fig. 44. Pot cultures of alfalfa, showing effect of adding different fertilizers. D9, nothing; D10, nitrogen; D11, potassium, and D12, phosphorus. Photograph from Oklahoma Agricultural and Mechanical College.

insoluble compounds, which the plants cannot use. The particles are very slowly changed into soluble compounds, and in this form are absorbed by the plants. The amount or per cent of soluble matter in the soil water at any one time is exceedingly small, as shown by the analysis of natural waters. In fact, if the amount should exceed ten parts in a thousand the effect would be unfavorable on the growth of the plant. The total amount of, say, potash in the soil may be several per cent of the total soil weight, yet the amount in solution at any time may rarely exceed fifty parts per million of water. It is well

that this is so, for, otherwise, the valuable soil constituents would be washed off to the sea by the percolating water. It is the great solubility of some substances, like nitrates, that explains their scarcity in the soil.

MINERAL MATTER DISSOLVED IN 100,000 PARTS OF
DRAINAGE WATER.

	Field No. 1	Field No. 2	Field No. 3
Potash.....	trace	trace	0.07
Phosphoric acid.....	trace	0.17	trace
Nitrogen compounds.....	10.27	21.17	2.79
Soda.....	1.43	3.10	1.24
Lime.....	6.93	10.24	2.23
Soluble organic matter....	10.00	10.57	8.00
Other substances.....	16.25	12.04	6.89
Total.....	44.88	57.29	21.22

113. Chemical Change in the Soil. The soil is the seat of constant changes, and these changes have great influence on the productiveness of the soil. When the soil is plowed, the particles are exposed more to the action of the air, water, frost, etc. When humus is put into the soil, acids are formed as the humus decomposes, and these tend to dissolve the substances in the soil.

114. Soil-Bacteria. Humus also encourages the growth of soil bacteria, because they live on plant and animal remains. These bacteria decompose the humus, and, in doing so, set free carbonic acid, which aids in dissolving the particles of soil. Thus it is that the bacteria of decay act beneficially on the soil. Other species of bacteria cause the formation of nitrates from ammonia or other nitrogen compounds or the free nitrogen of the air. No soil will long remain fertile unless the supply of organic matter is kept up.

115. Effect of Wheat and Barley Grown Continuously on the Same Land. Some results from the famous experiments of Lawes and Gilbert at the Rothamsted estate* are very instructive in showing the effect of growing crops continuously on the same soil. Wheat and barley, as well as other crops, have been grown on the same land through a series of years without manuring. Adjoining these non-fertilized crops were others treated annually with barnyard manure. Tests were also made of the effect of various other fertilizers. The results are given in averages for periods of eight years. They show that the annual application of manure increased the average annual yield twenty bushels per acre for wheat and thirty-two and one-eighth bushels for barley.

EFFECT OF CONTINUOUS CROPPING WITH AND WITHOUT MANURING.

	Wheat. Bus. per acre		Barley. Bus. per acre	
	Un-manured	Manured	Un-manured	Manured
8 years, 1844-51.....	17 $\frac{3}{8}$	28	...	...
8 years, 1852-59.....	16 $\frac{1}{8}$	34 $\frac{3}{8}$	24 $\frac{1}{4}$	44 $\frac{1}{4}$
8 years, 1860-67.....	13 $\frac{1}{2}$	35 $\frac{3}{4}$	18	52 $\frac{3}{8}$
8 years, 1868-75.....	12 $\frac{1}{4}$	35 $\frac{3}{8}$	14 $\frac{1}{2}$	49 $\frac{1}{2}$
8 years, 1876-83.....	10 $\frac{1}{2}$	28 $\frac{5}{8}$	14 $\frac{5}{8}$	52 $\frac{1}{4}$
8 years, 1884-91.....	12 $\frac{3}{4}$	39 $\frac{1}{4}$	11 $\frac{3}{4}$	44 $\frac{5}{8}$
8 years, 1892-93.....	9 $\frac{1}{2}$	33 $\frac{3}{4}$	10 $\frac{3}{4}$	49 $\frac{1}{2}$
Average 50 years	13 $\frac{1}{2}$	33 $\frac{1}{2}$	16 $\frac{1}{2}$	48 $\frac{5}{8}$

*Rothamsted Estate, Hartfordshire, England, the home of noteworthy investigations in agriculture under the Lawes Agricultural Trust, was founded in 1843 by Sir J. B. Lawes. These investigations, directed by Sir Joseph Gilbert and the distinguished founder for more than half a century, have had great influence in shaping the agricultural practices of the world.

CHAPTER XIII

IMPROVING THE CHEMICAL NATURE OF THE SOIL

116. What Plants Remove from the Soil. The amount of mineral food substances removed from the soil by a bountiful harvest is considerable. The object of fertilizing is not only to return to the soil the elements that help the growth of the crops, but also to improve the tilth. In applying fertilizers, we should remember that our effort is to bring about a twofold result: (*a*) to supply mineral food, and (*b*) to improve the texture of the soil. While, ordinarily, we add substances supplying soluble salts containing nitrogen, potassium, and phosphorus, it should be remembered that equally beneficial results are sometimes secured by applying dressings of substances that do not contain any considerable quantities of these elements, as lime, plaster of Paris, or gypsum. The benefits derived from these substances are due to the effect they have on the physical properties of the soil. The lime may also cause the decomposition of insoluble particles containing potassium or phosphorus. (Fig. 45.)

116a. Corn contains about 1.58 per cent of nitrogen; 0.37 per cent of potassium; and 0.57 per cent of phosphorus. How much of each does a crop of 50 bushels per acre remove from the soil?

117. Not All Soils Need the Same Fertilizer. Experiments have shown that the chemical analysis of a soil does not give a farmer a satisfactory guide as to what fertilizer to apply to his land. The analysis might show a high per cent of potash, and yet it might be in such

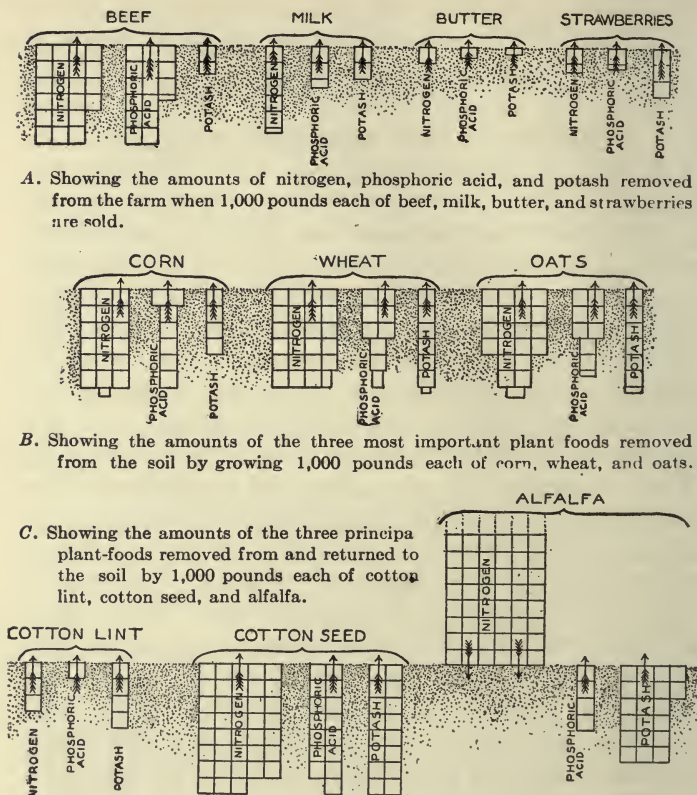


Fig. 45. Tables showing the amount of mineral food substances removed and returned to the soil by various crops.

insoluble combinations that the plants could not absorb it. This would not be the general rule, however. Usually, where the soil analysis shows a high per cent of an essential element, fertilizing with substances containing this element rarely gives returns above the cost of the fertilizer. The only safe rule by which to learn

the needs of a particular field is to make trials, using a variety of fertilizers, and thus observe what fertilizer gives most satisfactory results. These tests must be made for each soil formation. (See ¶ 133.)

118. Kinds of Fertilizers. Fertilizers are variously classed, according to the valuable element they supply, as "nitrogenous", "phosphate" or "potash" fertilizers. Substances containing all three constituents are termed "complete" fertilizers; or according to source, as home fertilizers, or commercial fertilizers. In most instances the substances applied to the land contain more than one valuable element, as, for instance, composts, which, being made out of plant remains, contain all the mineral elements found in plants.

119. Potassium Fertilizers. The most important source of potash fertilizers is the famous Stassfurt mines of Germany. The most common forms known to the markets are the sulphate, muriate and kainit—the latter a mixture of several salts. All are readily soluble and therefore are classed as "quick fertilizers." Wood-ashes form an important source of potash, though their value depends much on the source, and the way in which they have been cared for. If leached out by the rains, their value as a fertilizer is much lessened. Lime and gypsum often have the effect of potash fertilizers, causing the decomposition of insoluble potash compounds in the soil, and thus indirectly acting as potash fertilizers. The "home-made lye" obtained from ashes is largely potash.

120. Phosphorus Fertilizers. Phosphorus is an important fertilizer. Three-fourths of the phosphorus absorbed from the soil is deposited in the grain of the crop, and is, therefore, ordinarily sold from the farm,

while only one-fourth remains in the straw. Phosphorus compounds are widely distributed, though, usually, in insoluble compounds. Phosphorus is found in the soils combined with lime, magnesia, iron and alumina. For fertilizing purposes phosphates are obtained from bones, and rocks formed by the deposit of similar remains. In bones it exists as the insoluble lime phosphate. To overcome this, the rock or bone phosphates are treated with sulphuric acid which converts the insoluble into soluble compounds. When applied to the soil it soon returns to the insoluble salt, dicalcium phosphate. This latter is soluble in the presence of carbonic acid formed by the roots and decaying humus, and is hence readily available. (See ¶ 76.) Phosphorus fertilizers do not give beneficial results when applied to soils containing an excess of lime, like most of the "black waxy" soils.

Bone-black, formed by heating raw bones in the presence of air, is used in large quantities by sugar refineries. When it has served its purpose, it becomes a waste product and is sold for fertilizing. It has little value until treated with sulphuric acid. Bone-meal is the fresh bone ground and steamed and contains some nitrogenous matters in addition to the phosphorus.

The commercial supplies of phosphates are bones and phosphate rocks. The latter are mined in large quantities in South Carolina, Florida, Tennessee, Virginia and Pennsylvania.

121. Nitrogenous Fertilizers. Nitrogen is absorbed by plants as nitrates. The most readily available form is the "Chili saltpeter," found in large quantities in rainless regions on the western coast of South America. As it occurs naturally in the "saltpeter beds" it contains



Yield from one-tenth acre of cotton. No fertilizer.



Yield from one-tenth acre of cotton, with fertilizer containing phosphoric acid, nitrogen and potash.

Fig. 46. Some soils are made more productive by fertilizers.

a large amount of common salt, but when prepared for commerce it is a crude form of nitrate of soda. This is the form most used on quick-growing truck crops. It is readily soluble and, therefore, easily washed out of the soil. (See ¶ 127, Nitrification.)

Sulphate of ammonia is obtained as a by-product in the manufacture of illuminating gas from coal, and from the distillation of bone in the manufacture of bone-black. It is a very concentrated fertilizer, containing about twenty per cent nitrogen. Ammonia salts are readily converted into the nitrates by the nitrifying bacteria and are usually absorbed by plants in this form.

122. Guano, obtained from the habitation of flesh-eating birds roosting in caves and sea islands, has long been used as a fertilizer. Dried fish, blood, hair, leather, and various other substances of animal origin, are frequently used for fertilizing purposes. The nitrogen of both animal and vegetable origin must first be decomposed and converted into nitrates before it can be used by plants. This takes time, and hence such substances are slow-acting fertilizers. The meal, or pomace, obtained as a by-product in the extraction of vegetable oils, all contain large quantities of nitrogen, such as cottonseed meal, castor pomace, germ meal obtained from corn, etc. These substances are very valuable as feeds for stock. This does not preclude their use for fertilizing, for, in fact, they are almost as valuable for fertilizing purposes, after passing through the cattle, as before.

123. Composted manures are the most economical and, in general, the most desirable fertilizers. Besides supplying large amounts of nitrogen, they contain consid-

erable quantities of potash and phosphoric acid. The vegetable matter acts very beneficially, improving the texture and water-retaining property of the soil. An instance of the power of compost to maintain the land at a high state of productiveness has already been given (§ 115). Compost should be applied in the fall or early, winter and plowed or harrowed under. Covered barns prevent the loss in value of compost by scattering and leaching. Sometimes the compost is removed directly to the field. In many cases, where it is stored in bins, sufficient soil should be added from time to time to absorb the ammonia that is formed. When packed down closely to exclude the air, the loss from fermentation will be greatly reduced.

124. Fixation of Free Nitrogen by the tubercle-forming bacteria, found on the roots of plants belonging to the pea family, is the most important source of nitrogen known. By growing these legumes we add to the supply of combined nitrogen, and thus make the world richer. We do not recover all the nitrogen added to the soil in fertilizing. A part of it is lost by leaching, and a part by the escape of free nitrogen. All combined nitrogen may be used over and over again by plants and animals, but eventually it escapes back to the air as free nitrogen and, in this form, is available only to the bacteria which cause the formation of tubercles on the roots of legumes, and to a low class of microscopic plants. (See § 127, Nitrification.) Without these plants the world's supply of combined nitrogen would become exhausted. In the present state of our knowledge, only the "tubercle bacteria," and one or two other classes of bacteria, whose life-habits are little understood, are known to have the power of fixing free nitrogen.

125. Tubercles on Legumes. Plants belonging to the pea or legume family have small tubercles on their roots. (Fig. 47, *A* and *B*.) On opening the small tubercles found

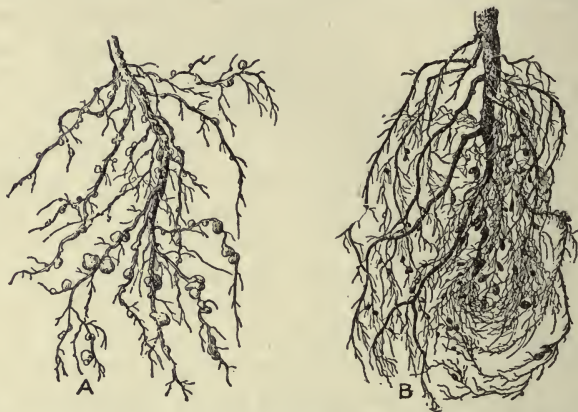


Fig. 47. *A*, root system of pea with tubercles. *B*, root system of alfalfa with tubercles. After Belzung

on the roots of beans, peas, alfalfa, blue bonnets, etc., we notice in the center a rose-colored area. If a bit of this is scraped into a drop of water, it becomes milky because of the hundreds of bacteria. They are so small that the most powerful microscopes are needed to make out their form. (Fig. 48.) It is these little plants that have the power to take the free nitrogen of the atmosphere and convert it into such form that the nodule-bearing plants, such as the cow-pea, may use it. Without these bacteria the legumes do not fix free nitrogen. It is this nitrogen-fixing power that makes these plants so valuable to us.



Fig. 48. Cell from tubercle of legume showing the bacteria.

126. How Legumes Enrich the Soil. By growing legumes (cow-peas, alfalfa, peanuts, etc.) the farmer is able to harvest a crop valuable as food for man, or feed for stock. These crops are especially valuable because of the large amount of nitrogenous or muscle-building substances which they contain. At the same time, strange as it may seem, they leave a larger quantity of nitrogen in the soil than was there before the crop was sown. The latter becomes available to other plants by the decay of the roots. This promotes the yield of the succeeding crop, as the following experiment shows: The plan of the experiment included two plots, "A" and "B." On "A" clover was grown the first year and barley the second. On "B" barley was grown both years. The increase in yield of barley on plot "A" over "B" is the measure of the manurial value of the roots of the clover left in the soil by the first year's crop.

Plot	Yield in first year		Yield in second year
A. Clover	Clover	Barley	69.4 bus.
B. Barley	37.3 bus.	Barley	39.1 bus.

Increase in yield due to clover roots. .30.3 bus. per acre.

The fixation of free nitrogen by the bacteria in the root nodules of the pea family has been thoroughly studied and is well established.

127. Nitrification is the formation of nitrates or salts containing nitrogen. Whenever vegetable or animal remains, like guano, cottonseed meal, composts and animal bodies, decay in the soil, the complex nitrogen compounds are broken up, and nitrates are formed. Nitrogen, which is so essential to plant life, is absorbed from the soil as nitrates. The nitrogen in the cottonseed

meal, for instance, must be converted into a soluble salt before it can be absorbed. This change is complex and is brought about by certain kinds of bacteria in the soil.

128. How to Promote Nitrification. Since the amount of nitrate nitrogen in the soil affects the yield of crops, particularly grain and forage crops, the question is often asked, "Can the farmer promote the growth of the nitrifying bacteria in his soils?" The answer is "yes." These bacteria are most active when the soil is loose, so that air can enter. These bacteria use large amounts of oxygen in making the nitrates, hence deep cultivation is the first essential to promote their activity. They do not grow in strongly acid soils. (See further in any encyclopedia, under "Saltpeter.") Nitrification is most active during the summer when the temperature is high. It ceases when the temperature of the soil falls below 50° Fahr.

129. De-nitrification is the destruction of nitrates. This is due to another class of bacteria, but, fortunately, the soil conditions that favor nitrification tend to retard de-nitrification. De-nitrification takes place in a serious degree, sometimes, when manure is not properly cared for; as when it becomes too dry, or when so wet that air is excluded. The same is true for the soils of the fields.

130. How the Soil Loses Nitrogen. The complex nitrogen compounds are usually converted into nitrates and absorbed by growing plants. If not absorbed, they may be destroyed by the de-nitrifying bacteria, or leached from the soil by percolating waters. They are quite soluble and, therefore, easily washed from the soil, particularly so from fallow soils through the winter months. The practice of leaving our cotton and corn fields fallow

and unplowed through the winter has much to do with the "wearing out" of the soils. A better plan would be to have the ground covered by some winter annual plant, such as oats, which could be grazed.

131. Green Manuring. Sometimes crops are grown with no intention of saving the above-ground portion for hay, but it is plowed under to increase the content of humus in the soil. While, in general, it would be much better to save the hay and, after feeding to stock, return the compost to the soil, there may be situations where it is desirable to turn the entire crop directly into the soil. When a crop is plowed under to enrich the soil, sufficient time should be allowed for complete decay before sowing another crop. The decaying plant remains often causes the soil to become quite acid for months afterward. Legumes are best for green manuring.

132. Relation of Texture to Fertilizing. The profit or loss resulting from the application of fertilizers depends much on the texture of the soil. Irrigation water and fertilizers are but poor and expensive substitutes for timely efforts to improve the texture of the soil. The best results from irrigation, or the application of fertilizers, may be expected only when the soil is in the most favorable tilth. "Tillage is manure."

133. Experiments on Soil Testing. In ¶ 117, mention was made of the desirability of testing the value of various fertilizing substances for any particular soil formation. Select a level piece of soil whose productiveness is to be tested under varying treatments, and lay out into beds, one (or two, or more, if desired) yard square. The location selected should be such as to give uniform conditions in all the beds, and all should be prepared alike. Fall-sown oats, wheat, or barley, are suitable

crops for tests in school gardens. From the usual amount of the various fertilizers applied per acre, we may calculate the amounts necessary for the beds. If they are just one yard square, divide the usual quantities by the number of square yards per acre (4,840), and the quotient will indicate the amount required for the beds. It is recommended that a space of two feet be left between the beds to guard against the possibility of the fertilizer in one bed affecting results in adjacent ones. The location should be one not subject to washing or flooding.

133a. Scheme for Field Tests of Different Fertilizers. Beds exactly one yard square. Walks two feet wide.

- | | |
|--------------------------------|-----------------------------------|
| 1. Land for beds plowed..... | 2. Harrowed, or raked |
| 3. Beds laid out and staked... | 4. Fertilizers applied |
| 5. Beds planted | 6. Quantity of seed to each bed.. |
| 7. Depth planted | 8. Plants appeared above ground |

Fertilizers	At the rate per acre in pounds	Quantity of lbs. applied to one square yard	Lbs. of crop harvested
Nothing (check).....	.....	.....	.....
Compost	10,000-20,000	2 lbs.	
Wood ashes	1,000-3,000	$\frac{1}{2}$ lb.	
Fresh lime.....	5,000-20,000	3 lbs.	
Common salt .....	.....	1 oz.	
Sodium nitrate.....	100-300	1 oz.	
Acid phosphate	200-400	2 oz.	
Nothing (check).....	.....	.....
Potash (Kainit)	100-300	1 oz.	
Combination—			
Soluble phosphate.....	200-400	1 oz.	
Sodium nitrate.....	200-300	1 oz.	
Nothing (check).....	.....	.....
Combination—			
Phosphate.....	.....	.....
Potassium nitrate .....	.....	.....
Nothing (check).....	.....	.....

CHAPTER XIV

PRODUCTIVENESS OF SOILS

134. Fertility and Productiveness Compared. A soil may be fertile, that is, rich in food elements, but not productive because of the presence of some harmful substance in the soil. A familiar example is the "clover sickness" of northern soils. A soil naturally suited to clover will grow several splendid crops, and then become "sick of clover," as they say, because clover will not thrive any longer. The soil is still rich in all elements of fertility, but not productive for clover because of some poisonous substance thought to be excreted or produced by the decay of the clover roots. If planted to other crops for a few seasons it will recover its former productiveness. The injurious results of even a single crop of



Fig. 49. Poisonous substances in the soil, formed by decaying vegetable matter, sometimes keep a fertile soil from being productive. (Wheat seedlings grown in: (1) Pure distilled water; (2) soil extract; (3) same soil extract from which the poisonous substances have been removed by absorption with carbon black.) Bureau of Soils. United States Department of Agriculture.

sorghum on some soils is much greater than could result from the loss of fertilizing substance removed by the crop. The effect is probably due to the formation of some harmful substance by the roots. These injurious substances are dissolved in the soil moisture. Deep plowing and the application of composts tend to overcome the bad effects of the poisonous substances.

135. Soil Conditions That Affect Production. The intelligent farmer watches his crop closely from day to day, and studies all the conditions that affect the vigor or fruitfulness of his crop, of which there are many. The general health of the plant may be affected as much by conditions above the ground as by conditions below the ground. If the plants are not growing properly, close observation will often lead one to discover the unfavorable condition, and a remedy for it.

136. Excessive Droughty Conditions are noticed by wilting, twisting, or drooping conditions of the leaves. The plants endure but do not make profitable growth when this condition exists, even for a part of the day. Where irrigation is not possible, prevention is the only remedy. (See ¶ 95, 105.)

137. Wet Soil Conditions often cause the leaves and stems to grow slowly and assume a yellowish cast, with splashes of purple. This condition is not the result of too much water in the plant, but of some injurious effect of water-logged soils on the roots. Many plants can be grown to full maturity with their roots in water, but not in a water-logged soil. Soils that frequently retain injurious amounts of water should be drained. (See ¶ 107.)

138. Soils Deficient in Essential Elements. Some soils do not have enough of some one or more of the essential

elements to suit the requirements of the crop. It is important in this particular to remember that forage crops need large amounts of nitrogen, and grain crops much phosphorus. The fruit crops require much potash. A soil may even be deficient in any one or several of the essential elements. The best and safest guide to learn the special fertilizing needs of a soil is to try by test. (See ¶ 133a.)

139. Chemical Elements May Not Be in Balance. A soil may contain so much nitrogen that the crop, say



Fig. 50. Showing the effect of an excess of lime and magnesia on plant growth. Excess of lime in pots on left; excess of magnesia in pots on right. Nearly equal amounts of each in center pots. From Bull, United States Department of Agriculture.

grain or fruit, goes all to wood and leaf and does not produce a harvest. In such cases, a potash or a phosphate fertilizer would be needed to balance the ration of mineral food. Sometimes some element, even an essential element, may be in excess. Plants require magnesium and calcium (¶ 43), but an excess of either may be the cause of a poor result. Fig. 50 shows the result of adding lime to balance an excess of magnesia in the soil, and shows the effect of balanced and unbalanced amounts of calcium and magnesium on plant growth. The good effects that sometimes result from the appli-

cation of lime may be due to the establishment of balance between the calcium and magnesium as just mentioned; to the effect on insoluble potassium or phosphorus compounds (§ 90); to a mechanical effect on the texture of the soil (§ 73); to the effect of lime in taking up an excess of acid in soils (§ 141); or in neutralizing some forms of alkali.

140. The Mechanical Condition of the soil may be the cause of unsatisfactory crops. Some crops, like wheat, do best with a settled sub-surface soil, while beets, potatoes and many other crops do best with a very loose soil. To have the proper mechanical condition of a soil for a particular crop is of great importance. It is in this particular that the farmer makes the greatest effort to improve the productiveness of his soils. Herein lie the most important problems of preparing and cultivating the soil. In improving the mechanical qualities, the important effects to be considered are:

- (a) The absorption of the rainfall;
- (b) The retention and movement of the water in the different layers of soil;
- (c) The circulation of air in the soil; and
- (d) The absorption and retention of the heat of the sun, and its loss by radiation.

While these properties are fixed, in a large degree, by the nature of the substance composing the soil, they may be greatly improved by the ordinary means of tillage. To know when to plow is just as important as to know how the soil should be plowed. Who can tell when and why, and how and why for plowing a particular piece of soil to prepare for a particular crop?

140a. The following topics are suggested for discussion: How many kinds of soils are in the school district? What crops are

grown. What yields are secured? Are the differences in yields due to the properties of the soil or to the way the soils are prepared or the way the crops are cultivated? Is fall or spring breaking preferred? What reasons do farmers give for justifying fall breaking or spring breaking?

141. Sour, or Acid, Soils are very unfavorable to some crops. Many soils are slightly acid, as will be found when tested with litmus paper. They differ greatly in the degree of sourness. Very acid soils are not favorable for alfalfa, cotton, etc.; but, for corn and small grains, no rule has yet been suggested. Soils that contain injurious amounts of acid are found in swamps or in sandy uplands.

141a. To Test Soils for Acid, use a small slip of litmus paper, secured from the druggist. Place the paper against the moist soil, and the color after some minutes will change. If blue, the soil is alkaline; if red, it is acid. More reliable results will be secured if the soil is extracted in distilled water, and then tested with litmus or other indicator.

141b. To Test Soils for Free Lime, drop a small lump into a glass of strong vinegar. If lime is present bubbles will continue to stream from the lump for some minutes. Soils with free lime present are not acid.

141½. Alkali Salts in a soil may be the cause of unproductiveness. There are several kinds of very soluble salts that accumulate in the surface soils, most frequently in regions of low rainfall. Often the dwarfing effect of alkali salts is confined to a low place, a wet-weather seep, or other place where a quantity of soil-water is evaporated. These salts are formed in all soils, but where the rainfall is abundant they are washed out of the soil by percolating water. If the rain is all evaporated from the surface, it will cause an accumulation of these salts near the surface to such an extent that injury to the plant results. Lime is sometimes beneficial on such soils.

CHAPTER XV

ROTATION OF CROPS

142. Rotation. The amount of mineral food which a crop will take from the soil varies with the kind of crop, depending on how much of the crop is removed by the yearly harvest, the richness of the land, and many seasonal features which are too complex to be discussed here. By referring to the table in the appendix it will be seen that the amount of nitrogen removed by the grain crops is less than the amount removed by crops grown for their roots. It will be noticed, also, that grain crops remove or require large amounts of phosphorus; root crops, potash; and hay crops, much nitrogen; an exception being made for legumes like alfalfa, clover, or cow peas when grown as hay crops (§ 117). Some legume crop should be included in any system of rotation.

143. Order of Succession in Rotation. It is desirable to arrange the rotation so that the same land does not have the same crop twice in succession. In arranging the crop it is important to consider the order in which the crops should follow each other. Plants with shallow roots should follow plants with deep-feeding roots; non-cultivated crops, like grain, should follow cultivated crops, because the land will be in better tilth. As regards the predominating mineral foods, it is better to let those crops requiring large amounts of nitrogen follow potash-loving crops, or, still better, legumes, because they will leave additional amounts of nitrogen in the soil which

will be very beneficial to the grain, but not so necessary to the others. Fig. 50a shows the difference in a crop of oats grown on soil previously green-manured with a crop of mustard (a non-legume) and when green-manured with a crop of vetch. This result shows strongly the need of including some legume in any sort of rotation. In some soils cover crops or heavy applications of fresh manure tend to cause too rank a growth of straw in the small grains. In such cases it is advisable to allow a crop of corn to come before the small grains.



Fig. 50a. Oats grown on soil previously sown to mustard and vetch.

144. Cover Crops; Catch Crops. Except in arid regions, it is best to keep the land constantly occupied by some crop. They not only keep the land continually earning something, but it is best for the land. A field that is bare or fallow loses more by washing and leaching than when occupied by plants. It is often possible to grow a quick-maturing crop after the principal crops have been harvested, for example, June corn after potatoes or small grain; cowpeas after corn.

145. Marketable, or Usable, Crops. In planning a rotation or selecting a cover crop, it is necessary to consider what may be successfully sold, or used to advantage. This will depend on the markets and the farmer's facilities for keeping and feeding certain kinds of crops.

146. Other Advantages of Rotation. Besides preserving the soil nutrients, providing for their better dis-

tribution, facilitating fertilizing, rotation (which is closely related to diversification) affords other advantages:

(a) *Tends to free the land from noxious weeds*, as where oat stubble is planted to June corn, the late cultivation of the corn prevents the seeding of the weeds, such as cockle burs or Johnson grass.

(b) *Exterminates insect and fungous diseases*. Insect and fungus pests usually attack only particular kinds of crops. If the same crop is grown on the same land year after year, the larvæ of insects and spores of the fungi lodging in the ground during the fallow season will find their food ready when the season is ready for them to multiply. (See ¶ 217 and ¶ 228.)

(c) *Avoids the injurious effects of growing the same crop continuously on the same land*. Recent investigations have shown that the decreased yields resulting from growing the same crop on the same land from season to season is due not only to the loss of mineral nutrients, but also to the formation of toxic substances (¶ 134) in the soil. These toxic substances are not usually injurious to other crops, though there are cases known where one crop will leave substances in the soil poisonous to some other crop.

147. Distributes the Labor. Rotation and diversification make it possible for the work to be more evenly distributed through the year. Not all the crops will need to be planted, cultivated or harvested at the same time. The farmer will thus be able to keep busy, and not have to pay out so much for help during rush seasons that come with a one-crop system of farming.

CHAPTER XVI

RELATIONS OF PLANTS ABOVE THE GROUND

148. We have now found out a few things about the relation of the plant to the soil. Soil culture, we found to be making a home for the roots. What can we do to make the conditions above the ground more favorable to the growth of the crops?

149. Provide for Leaf Development. All the carbon in plants, which is fully half their substance, is absorbed from the air by the green leaves, and, through the agency of sunlight, made into plant substance. The leaf is a part, or organ, where the raw materials are brought together and made into the foods that nourish the plant. It is plain, then, that in husbanding plants provision should be made for normal leaf development. Leaves will not grow unless plenty of light is present. This is shown when plants are grown in darkness. We have often noticed how the leaves arrange themselves so that they get the greatest benefit from the rays of light. Plants growing beside a wall or in a window turn their leaf surfaces toward the light. Vigorous leaf development is possible only when plants are far enough apart to not unduly shade each other. Too many plants must not be allowed to grow on the same ground, whether they be weeds or all of the crop planted. When the plants are too close together, the leaves and side branches do not grow, and the stem spindles up in an effort to reach the best light. The individual plants are thus weakened, and are more subject to the attack of insects

and fungi. Weak, poorly nourished plants are not fruitful. Healthy plants have large leaves. Large leaves indicate vigor. The rank-growing weeds have large leaves. Increasing the amount of leaf surface is increasing the capacity of the plant to manufacture plant substance.

150. Relation of Leaf Surface to Soil Moisture. The total leaf surface on a plant may be several times the total ground surface shaded by the plant. If evaporation is increased by the winds or high temperatures, it may happen that the supply of soil moisture may become exhausted and the plant suffer. Soils covered with plants lose their moisture faster than if they are bare or fallow. In regions of slight rainfall, therefore, it often becomes desirable to reduce the number of plants to prevent too great a draft on the stores of soil moisture. This is an additional reason for leaving space between the individual plants in a crop. (See ¶ 102.)

151. How Far Apart Should Plants Be Grown? Where the value of the crop depends on the perfect development of the individual plant, or some special part, such as the leaves, flowers, fruits, stems, or roots, sufficient space should be allowed that adjacent plants will not interfere with each other. However, the value of the crop often depends more on the total weight of the harvest than on the quality of the individual plants. In such cases, the loss from a limited amount of shade will be more than made up by the increased number of plants, as in the case of the grain crops. Again, the fertility of the land also affects the size of the plants, and, of course, the space which each should be allowed. Often the use for which the crop is intended must be considered, as, for instance, in the case of sorghum grown

for syrup or for forage; corn grown for ensilage or for grain.

152. The Vigor of Leaves and Stem Growth. The size of leaves is influenced largely by the amount of water available to the plants during the period of their formation. From this, it follows that plants grown for their leaves, like cabbage, lettuce, hay crops, etc., do best when plenty of moisture is in the ground. Light is necessary for the formation of leaves, as we have seen. Where branches are shaded, the lower leaves are small and weak, and often fall off before the season ends. As the buds, from which the branches, leaves and flowers of the succeeding season grow, are formed in the axils of the leaves and take their vigor from them, it is important that fruit trees be pruned out so that light may reach to all parts. (See Chapter XVIII.)

153. The Temperature of the Air is subject to great and often sudden variations, whereas the soil, as we have seen, changes its temperature very slowly. The above-ground portion is more often injured by extreme cold or excessive heat than the part below the ground. The first effect of lowering the temperature is to retard the growth of the plant. Cold does not permanently affect all plants alike. Some plants are killed by moderately low temperature, while others are uninjured even by long exposure to severe freezing. The ill effects of freezing are more severe on plants when full of sap. Peach trees may endure a number of severe freezes through the winter, but if a severe cold spell comes late in the spring, after the buds have swollen, the injury is often considerable.

Sometimes the bad effects are due to the sudden thawing, more than to the cold itself. The winter-killing

of the cambium layer is often confined to the east side of a tree where the early sun rays cause a sudden warming. Delicate plants, fruits, etc., may often be saved by protecting from too rapid thawing; by shielding from the sun's rays, bathing in cold water, etc.*

154. Buds and Nodes. If we examine the branches of almost any shrub or herb, we shall find that they are divided into segments by the buds at the nodes. We have already found a reason for calling the former nodes, and the spaces between, internodes. The buds are formed just above, or, as the botanist says, in the *axil* of the leaf, which readily explains the observation that the vigor of the buds is determined by the size of the leaves which nourish them. The bud at the end of the shoot, called the "terminal bud," is usually the most vigorous; but, as a rule, the vigor and the size of the buds decrease as we pass down to the beginning of the season's growth. This is often due to the subsequent shading of the lower leaves,—often to the extent that they turn yellow and fall off.

155. Structure and Classification of Buds. If we examine some large buds, such as the buckeye, sycamore, or fig, just as they unfold their leaves in the spring, it will be very plainly seen that the bud scales are only transformed leaves, hence they are called scale-leaves to distinguish them from normal leaves. These scale-leaves cover up an embryo branch—a branch having miniature leaves, nodes and internodes. Nature formed these buds, or embryo branches, early in the preceding season. Note also that more buds were formed than are likely to grow into branches. (Fig. 52.)

*For excellent full discussion of the effects of temperature on plants, and the proper treatment to lighten the bad effects, reference should be made to Goff, *The Principles of Plant Culture*; Bailey, *The Principles of Fruit Culture*.

156. Leaf Buds and Flower Buds. If we notice the buds on peach or plum branches from January until spring, we shall see that not all the buds are the same size or shape. Some are pointed and slender, and will form a cluster of leaves when they burst forth in the spring, and are hence called *leaf buds*. Others are broad and rounded: these buds are flower buds. They are some-

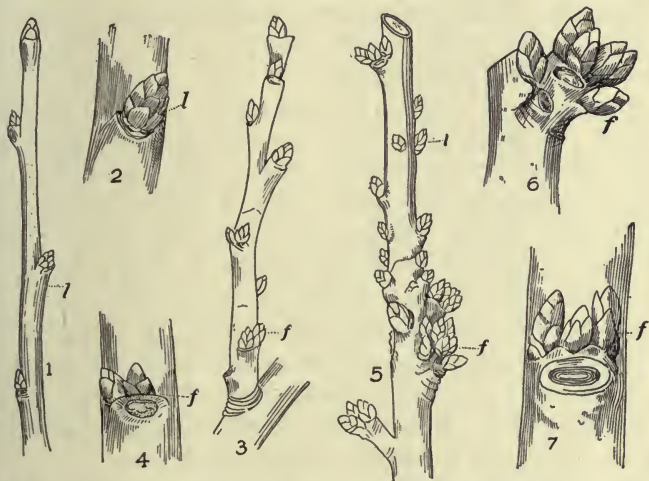


Fig. 51. Leaf buds and flower buds of plum. 1. Shoot bearing leaf-buds only. 2. A bud of same enlarged. 3 and 5. Branches having leaf-buds and flower-buds. 4, 6 and 7. Buds of same enlarged. Flower-buds at *f*; leaf-buds at *l*.

times called fruit buds, but, of course, the flower must always precede the formation of the fruit, so it is best to call them *flower buds*. Just below each bud is a leaf scar. Sometimes we shall find the leaf scars, though the buds are apparently not there. They are there, however, but too small to be seen. They do not grow unless the end of the branch is removed. Such buds as do not grow except when stimulated are called *latent buds*. (Fig. 51.)

157. How to Distinguish Flower Buds. Flower buds are formed the same season that the leaf buds are, though it is not always easy to distinguish the two kinds till some time after the fall of the leaves. The position of the bud is often an indication of its kind. We notice, in the plum twigs illustrated in Fig. 51, that the flower buds are on the side of the leaf buds. We also noticed that the flower buds were found only on the wood of last season's growth. The "bearing wood" of the peach, plum, and other similar stone fruits, is formed in the season before the flowers appear. Good crops of fruit cannot be had from trees of this class unless sufficient bearing wood is made the preceding season. In the case of the apple, pear, quince, etc., the flower buds are formed less regularly. They occur on the ends of small side branches that are from two to five years old. The shape and place of appearance of the flower buds vary very much in the different classes of fruits. It is important that one should know how to recognize them and to know the time of their formation as well. It often gives valuable information as to how and when to cultivate and prune. For illustration, take the grape. The flower clusters are found on the current spring shoots, hence we prune heavily to promote the formation of new wood.



Fig. 52. Diagram of a section through a bud. V, the apex; 1, 2, 3, 4, successively older leaf rudiments; A, B, C, successively older branch rudiments; D, E, vascular bundles. After Hansen.

158. Formation of Flower Buds. In plants that are esteemed for their flowers or fruits, it is desirable to know all the conditions that promote the formation of

flower buds. Some sorts are naturally more inclined to form flowers than others, still we can promote the fruitfulness of the plants by giving them proper treatment. Every one has noticed that the trees bloom more profusely some seasons than others. This has led many persons to study the conditions that induce the formation of flower buds.

159. Conditions That Promote the Formation of Flower Buds. Flower buds are formed in the greatest abundance when the reserve food is considerably in excess of the current needs of the plant. If a plant is growing too rapidly, using up all the food as fast as the leaves make it, flowers are not formed in abundance. They may be stimulated to form flower buds by checking the growth, either by reducing the water supply, by removing the tips (terminal buds) of the shoots, or by restricting the growth of the roots. When plants are young, or just at the opening of spring, in the case of fruit trees, they grow very rapidly. Flower buds already formed will open, but new ones are not formed till the warm, dry winds have checked the rapid growth of the shoots. This checking of the growth allows the formation of reserve food in excess of what the plant is using for growth. *To encourage the formation of the flower buds, then, we should promote the accumulation of reserve food.*

160. How to Promote the Accumulation of Reserve Food. Experience has shown that the three following rules are safe guides:

(a) *Provide favorable conditions for food formation in the leaves.* Light and a free circulation of air are essential. These may be secured by giving the plants plenty of distance, or by pruning out useless branches. The normal healthy conditions of the foliage should be pre-

served. Plants suffering from the attacks of insects or fungi are not fruitful because they are imperfectly nourished.

(b) *Provide the roots with the proper amounts of phosphoric acid, potash, and nitrogen.* An excess of nitrogen tends to favor growth of leaves and shoots at the expense of flowers. Phosphorus and potash favor the formation of flowers and the full development of the fruit and seeds.

(c) *Check any unusual or unnecessary growth of the stems by withholding excessive supplies of water.* This check to the growth naturally results when the warm weather of the summer sets in. Where the plants are grown under glass it is often possible to regulate the time of flowering by controlling the water supply.

161. Fruiting in Perennial Plants is sometimes so excessive that they are greatly damaged. Fruit trees "overbear" to such an extent that they exhaust all the reserve food, and the flower buds do not develop for the succeeding crop. This gives rise to the habit of producing a crop every other year, noticed in apples and peaches.

162. Sterile Plants, or other plants that are kept from fruiting, tend to become perennial. If the formation of fruits is prevented or removed while young, they continue to grow and form new flowers. In this way, sweet peas, nasturtiums, and other plants grown for their flowers, have their blooming period prolonged. Garden plants of which the fruit is gathered immature, as beans, cucumbers and okra, grow much longer than they would if the first fruits formed were allowed to mature and exhaust the plant. Clover, grown so extensively in the North and in some southern states, is a biennial; though, if prevented from fruiting, it becomes a perennial.

CHAPTER XVII

THE OFFICE OF FLOWERS

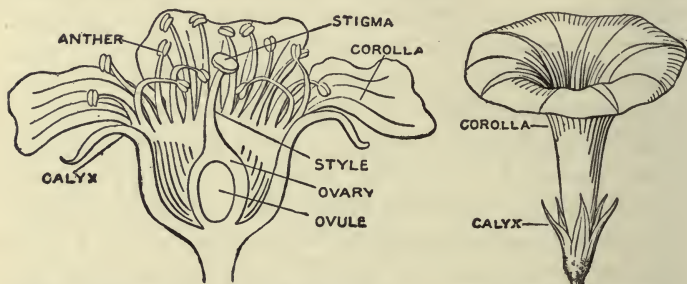
163. We have already mentioned some of the conditions that promote the free formation of flowers. We might call it the conditions necessary for fruitfulness, for the flower is only a step in the formation of the fruit and seeds. Some plants are cultivated only for their leaves, stems or roots—as cabbages, lumber trees, or potatoes. Most plants, however, owe their value to the crop of seed or fruit which they bear. In the latter class, including the fruits and grains, it is not only necessary that the flowers be formed, but that they should form seed abundantly. They must “set seed,” as the farmer says. To understand this process, we must know more about the structure and the use of the different parts of a flower.

164. Structure of Flowers. Flowers are very varied in their form, size, and in the arrangement of their parts. If we should closely examine a flower of a peach or a geranium, to take familiar examples, we shall find that it has several parts, each of which contributes some service to the success of the plant’s effort to form seed. We have already learned that a seed is usually an embryo plant, with a store of reserve food, both inclosed in a protecting case called the *seed coat*.

165. The Names of the Parts. We must learn the parts of a flower and their names. We first notice the brightly colored petals. They attract our attention and that of the bee also. The bee long ago learned to recognize

these brightly colored parts as sign-boards directing it to the nectar below. The pleasant scent or odor serves the same purpose.

166. There are five petals in the peach-blossom, all separate, but in the morning-glory they are united. Whether united or separate, taken together they are termed *corolla*. (Fig. 53.) Just below the corolla there are usually five small green leaves which are named *sepals*, and, when taken together, the *calyx*. The corolla and



Peach-blossom cut open, to show the parts of the flower.

Calyx and corolla of Morning-Glory.

[Fig. 53. Peach-blossom and morning-glory.

calyx were called the floral envelope by the older botanists. Inside of the corolla are a number of small yellowish masses on slender stalks. These yellowish bodies are called *pollen cases*, or *anthers*. When ripe, they produce the fine yellow dust, or pollen. In the center of the whorl of stamens is the *pistil*. There are three parts in the pistil. At the top it usually has a slightly knob-like portion called the *stigma*, covered with a thick, gummy liquid. The stigma is sticky, to catch and germinate the pollen brought from its own or other flowers. Below the stigma is a slender portion, the *style*, and then the swollen base, the *ovary*. The ovary is the part that

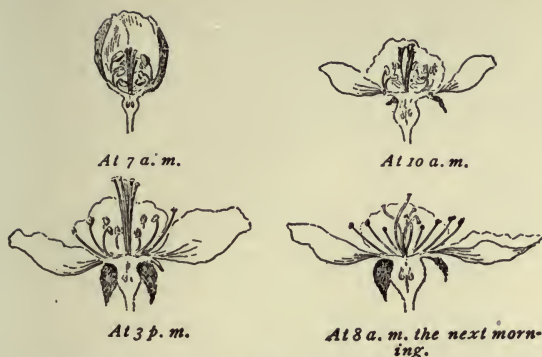


Fig. 54. The opening of a flower of Kieffer pear, showing the unfolding of the parts in blooming. The flowers of pears and apples have five styles and stigmas. All natural size. From American Gardening.

grows after the other parts of the flowers have fallen. It becomes the cherry with its seed, the pea pod, the corn grain, the pecan with hull, etc.

167. Use of the Parts of the Flower. Now that we have examined a flower and learned to recognize the parts, we want to know what these parts do. We have already learned that the bright color of the corolla serves to guide the bee or butterfly, or other nectar-eating insect, to the

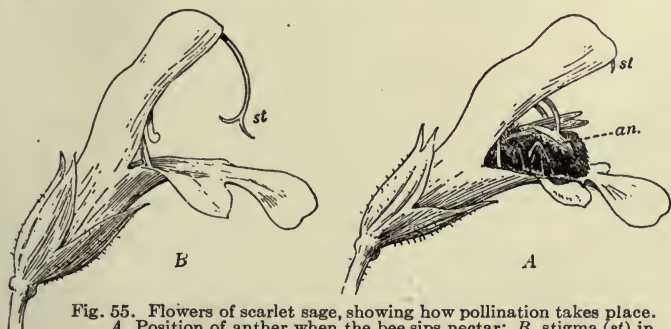


Fig. 55. Flowers of scarlet sage, showing how pollination takes place. A, Position of anther when the bee sips nectar; B, stigma (st) in position to be pollinated.

drop of food at the base of the ovary. When the bee enters the flower to gather bee-bread (pollen) and the honey, or nectar, at base of pistil, some of the pollen is lodged on its head and legs and body. When it enters the next flower, some of this pollen is caught by the

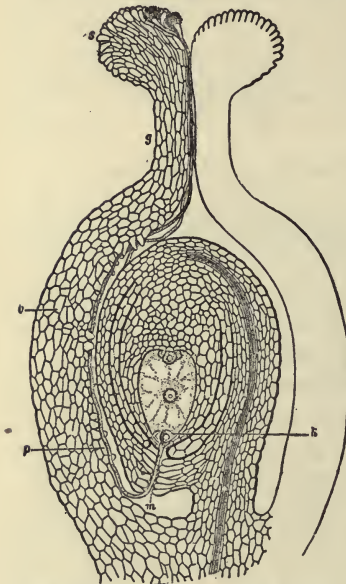


Fig. 56. Diagrammatic section of ovary and ovule at time of fertilization. *m*, micropyle; *k*, egg cell; The pollen tube has grown down through the style, between the walls of the ovary and ovule, to the egg cell, *k*, of the embryo sac.

stigma. (Fig. 55.) Many kinds of flowers are solely dependent on the going and coming of insects to bring about pollination and, therefore, the formation of fruit and seed. We used to think that flowers had their gorgeous colors to please man's fancy. We now know that it is to attract the lowly insects. Usually, night-blooming flowers are white and give off their odors more strongly at night (study the tuberose, rain lilies, night-blooming cereus, moon-flowers, etc.), in order to attract the night-flying moths. Blue and red flowers are day bloomers.

168. Growth of the Pollen Grains.

The pollen grain is a very small body, consisting of one or two cells. When it is deposited on the moist stigma, it begins to grow a slender tube (pollen-tube) down into the ovary.

169. Fertilization. The pollen-tube produces a small cell that contains a nucleus that passes into and unites



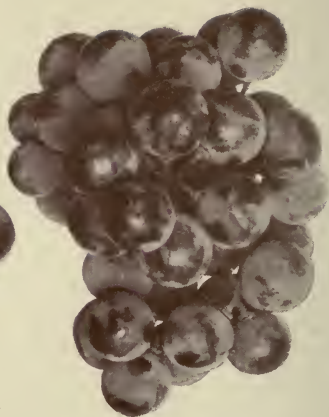
"LAST ROSE"

A HYBRID Produced by PROF. T. V. MUNSON, Combining the FOX GRAPE of the North, POSTOAK GRAPE of Southwest, and WINE GRAPE of Europe

1



2



3



4

5

6

7



8

9

The result of pollenizing the Herbert grape with different varieties.

1, By Niagara,	4, By Herbert,	7, By Eldorado,
2, By Worden,	5, By Brighton,	8, By Lindley,
3, By Catawba,	6, By Merrinack,	9, By Salem.

After Beach, New York Experiment Station.

with the female cells in the ovule. (Fig. 56.) This process is called fertilization or fecundation. When fertilization takes place, the fruit is "set" and the ovary begins to grow. The corolla, stamens, etc., wither and fall away. If fertilization does not take place, the entire flower withers and dies in most cases,—the exceptions being the fleshy seedless fruits, as seedless grapes and oranges.

170. The Growth of the Fruit and Seeds. After fertilization, the ovary and, in many plants, other adjacent parts, begin to grow rapidly. The reserve food of the stems moves rapidly through the little twig that supported the flower into the fruit. The fruit contains the seed. Seed production exhausts the plant. Nearly all the reserve food passes into the seed and fruits. Often more than half of the substance of a plant is collected into the seeds, as in common field corn.

171. Importance of Pollination. Pollination and fecundation are necessary for the growth of the fruits and seeds, except in some kinds of seedless fruits, like the banana. In some varieties of strawberries the pollen is not produced in sufficient quantity to cause the fruit to set. In such cases it is usual to plant varieties producing pollen freely, in alternate rows. (Fig. 57). The bees, going back and forth from one variety to the other, carry sufficient pollen to make the fruit set on the fine sorts. Some varieties of plums and pears, while producing pollen, are



Fig. 57. Flowers of the strawberry. A, a flower having both stamens and pistils; B, flower of a kind having pistils only.

sterile to their own pollen. Many varieties of grapes also do not set fruit when pollinated with their own pollen. The illustration facing page 115 shows the



Fig. 58. Injurious effect of self-pollination shown in pile at right. After Hartley, United States Department of Agriculture.

effect of pollen of several varieties of grape on the Herbert grape. Some varieties make good pollinizers while others do not. If one is planting Herbert grapes, other varieties should be planted nearby to furnish pollen. In the same way, an orchard of Kieffer pears will be more fruitful if trees of other varieties are in the orchard. The bees will carry the pollen back and forth as they go from flower to flower. Sometimes in long-continued rainy weather during the flowering season a full crop of fruit is not set, because the bees are unable to visit the flowers freely.

172. Not All Plants Pollinated by Insects. Some plants, like wheat, oats, cotton, beans, etc., are ordinarily self-pollinated, that is, the pollen in the flower is produced so that it naturally falls on the stigma. Many other plants, as the pine trees, field corn, willows, etc., are solely dependent on the wind to carry the pollen from one flower to another. There are many interesting adaptations for bringing about pollination, which cannot be discussed here.

173. Cross-Fertilization is Important in many plants. There are many plants that are normally self-fertilized and whose progeny do not seem to lack vigor. However, most plants give better seed from cross-fertilization, that is, having the pollen to come from different plants. Seeds originating from normal cross-fertilization are usually more vigorous, healthy and productive than seeds resulting from self-fertilization. The Illinois experiment station found a difference of about ten bushels per acre in the yield of corn between seed produced by cross-fertilization (Fig. 58) and that by self-fertilization.

Continuous self-fertilization leads to complete sterility in plants that are normally cross-fertilized, as corn, etc. Fig. 59. Darwin found that after eleven generations of self-fertilization the scarlet runner failed to set seed, while the plants produced by as many generations by cross-fertilization were much more healthy and fruitful than the original stock.



Fig. 59. Effect of inbreeding. A, Cross-bred; B, inbred five years. From Bulletin, Illinois Experiment Station.

CHAPTER XVIII

PRUNING AND TRAINING PLANTS

174. The Pruning and Training of Plants have for their object the improving of the relations of the plant to the sunlight and air. They are very old arts, that were well developed before we understood how the sunlight and air were of use to the plant.

175. The Effect of Pruning. The practice of improving the usefulness of plants by removing some part is founded on the the principle that suppression of growth in one part stimulates growth in others. The *manner* and *season* of pruning govern the result.

176. Pinching. If we should pinch out the terminal bud from a leafy branch during the rapid-growing season of spring, as shown in Fig. 60, it would result in a temporary check to the lengthening of the branch and a more rapid swelling and better nourishing of the buds below. If only the tip were removed, probably only one of the buds left—the uppermost—would form a new shoot. This would soon grow out and take the place of the one removed. This pinching usually



Fig. 60. Pruning by pinching.

gives a stocky growth to the branch and favors the formation of fruit-buds (§ 159).

177. Summer Pruning of Blackberries. If the new shoots of blackberries be pruned off, the buds below will form several branches. As the fruit of the following season will be borne on this growth, we see how summer pruning may increase the fruitfulness of blackberries.

178. Light Pruning in the Dormant Season stimulates branching. If a branch, like the one shown in Fig. 72 on page 127, were pruned at X, two, or possibly three, of the next lower buds might grow into fairly vigorous leafy branches, with many strong buds. If left unpruned, it would probably grow straight out, forming a slender shoot with very feeble side branches, too poorly nourished to form many fruit-buds. Thus we see that pruning may stimulate branching, thickening of the stems, and a freer formation of bearing wood (branches with flower-buds). This kind of pruning is often practiced on all kinds of orchard trees and berry plants, and is frequently referred to as "cutting back" or "heading-in." This kind of pruning is quite necessary for the first few seasons' pruning of newly set orchards.

179. Why Prune Plants? We see from the illustration given that pruning may be used to (1) check growth, (2) induce branching, to give correspondingly more leaf surface. The latter causes the branches to be better nourished and, hence, to grow thicker and form more flower-buds. (See § 159.) Any kind of pruning that retards growth tends to increase fruitfulness and a better ripening of the branches. Pruning is sometimes objected to, with the idea that nature knows what is best for the plant. Persons who advocate no pruning forget that orchard plants are grown in an environment that

leads to an unusual development of the branches, and that such unusual growth does not favor the development of fruitfulness (§ 159). Practical experience has long proven that the proper pruning of orchard trees makes them fruitful and profitable. Pruning is not merely removing so many branches or brush. The pruning should be done at the place that will produce the desired result. Herein lies the value of an understanding why and how pruning should be done.

180. Pruning to Stimulate Growth. Sometimes a plant or tree will cease to make the normal amount of healthy growth. If such condition is not the result of improper soil conditions, very severe pruning of the branches may bring about a renewal of active growth. Very old orchard trees are sometimes improved by a severe pruning. Pruning of orchard trees or shade trees may be overdone, producing such a shock that the plant is weakened rather than stimulated.

181. Pruning to Hasten or Delay Maturity. Pruning to hasten maturity is seldom practiced except on nursery stock (removing the leaves), or on tobacco plants. It is usual to remove the seed-pods from flowering plants, such as sweet peas, etc., in order to prolong the flowering period. The



Fig. 61 An example of thinning. After Goff.

food substance that would be used in maturing the seed is used to build new flower-buds.

182. Pruning to Protect Plants from disease and mechanical injury is often necessary. Dead branches may fall and do much injury to the other limbs unless removed; or, they may become diseased by the fungi of decay and transmit the disease to the heart-wood of the trunk, thus making the plant weaker. Fig. 62. Dead or diseased branches, such as pear blight, should be cut off below the diseased part, and burned to prevent the spread of the disease.

183. Thinning Fruit is a form of pruning. It often



Fig. 62. Effect of improper pruning. The larger stump became diseased and the heart-wood in turn. The fungus mycelium caused the heart-wood to decay, as shown in the cross-section. The fruiting fungus is shown at A. From photographs by Prof. Geo. F. Atkinson.

happens that a fruit tree will set more fruit than it should mature. Nature causes many of these young fruits to fall off, but not always sufficiently. Where too much fruit is left on the branches, the trees "overbear," with the result that they do not prove fruitful in the season following. All the reserve food is used up in maturing the crop and, therefore, flower-buds are not formed. (See ¶ 159.) Another good reason for thinning is found in better quality of the fruit. A dozen good peaches will sell for more than a gallon of "pie peaches."

184. Root-pruning. In healthy plants there is a balance between root-surface and leaf-surface. If a plant is growing too vigorously, it may be checked by running a spade into the ground to sever some of the roots.



Fig. 63. Tree properly pruned before setting out



Fig. 64. A badly shaped top, due to not cutting back when set out

185. Pruning Transplanted Plants. In transplanting plants many of the roots are destroyed, thus destroying a natural balance. Transplanted plants, especially woody ones, should have all injured and extra-long roots removed and the top cut back correspondingly. (Figs. 63 and 64.)

186. How to Make the Cuts in Pruning. When a branch is removed, we expose a part of

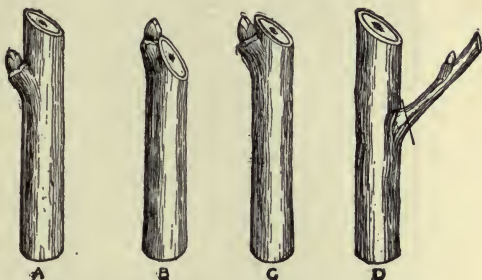


Fig. 65. *A*, cutting too far above the bud; *B*, cutting too close; *C*, the cut as it should be; *D*, removal of a branch, the cross-line indicating the proper place for the cut.

the cambium and woody portions. Unless this is quickly healed over, the wound may become diseased, and the entire plant, in turn, before the callus grows over the cut surface. It is important, therefore, that, in pruning, nothing but sharp instruments be used, so that the cuts will be smooth. Not only should suitable tools be used, but care should be exercised to make the cuts so that the least amount of callus will be needed to close the wound. Callus cells are nourished by the reserve food. This suggests that the line of cut should be close to the supplies of reserve food. If a small branch is to be cut off, make the cut close to a bud, as shown in Fig. 65 *C*. The bud will grow out and the cut will heal over. If cut too far above the bud, *A*, a dead stub will remain that cannot be healed over. If cut too close to the bud, *B*, the bud will die, and we have a stub the full length of the internode. Side branches should be pruned close up to the main stem, *D*.



Fig. 66. Showing proper position and angle of cut to use in removing large limbs.

Roots of transplanted plants should be severely pruned. It is not the length of the roots left that favor the plant, but the quickness with which new branches with root-hairs are formed. Severe pruning promotes vigorous branching in

many plants, notably the strawberry, celery, etc.

187. In Removing Large Limbs, extra care should be taken to get the cuts at the proper place and angle.



Fig. 67.

Fig. 68.

Fig. 69

Healing of properly made cuts. Photographs by Prof. F. A. Waugh.

Figs. 66, 67 and 68 are good examples. We have already noticed the bad results from improper cuts, as shown in Fig. 62. (See ¶ 59.)

188. Pruning Orchard

Trees. Before we can intelligently prune even young orchard trees, it is necessary to decide on the arrangement of the branches desired in the matured tree.

Whatever the number and arrangement of the branches, they should be low enough to allow the fruit to be gathered easily, and high enough not to interfere with the easy care and cultivation of the ground. Some prefer to have the outline of the pear trees pyramidal, with a central supporting trunk, such is shown in Fig. 70.

For most orchard trees, possibly for pears also, it is preferable to have a number

of strong branches starting out from two to four feet from the ground. That portion from which the leading branches start is called the *head*. This gives an open center to the tree and allows more light to the smaller interior branches, and keeps even the top of the tree within reach. Fig. 71 shows the framework of an open-headed tree. Fig. 72 shows the starting of such a head,

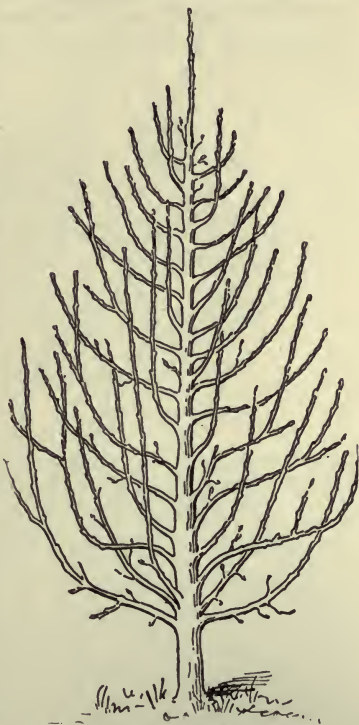


Fig. 70. Pyramidal form of top.

and Fig. 73 further thickened and made stocky by "heading in." The branches should not start out from the same place, as illustrated in Fig. 74. Such branches often split out when strong winds prevail.



Fig. 71. Open-headed tree; vase form of top.

189. Pruning and Training Grape-vines. The stem of the grape is too weak to stand without support. In nature it grows over the outer branches of trees, sometimes forming a canopy over the tops of small trees. Cultivated grapes are given supports made with posts and smooth wire. In order to keep the bulk of the vines within limits and to increase their fruitfulness, they are severely pruned every winter. This heavy pruning

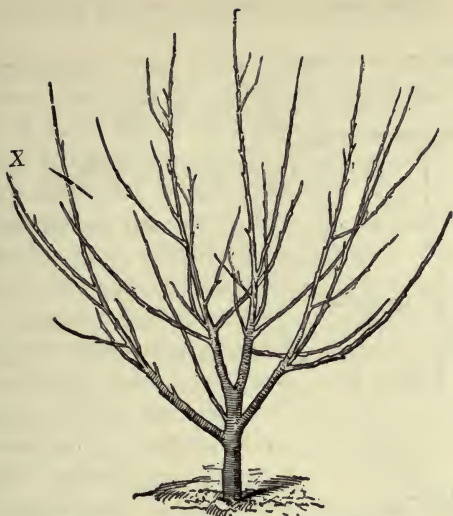


Fig. 72. Starting of an open-headed tree.

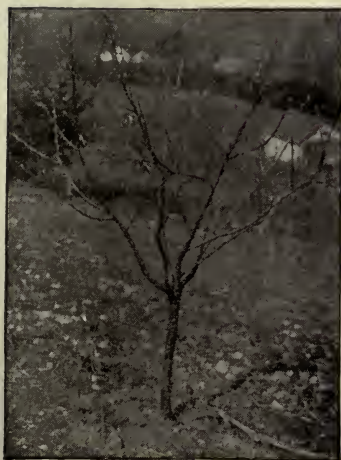


Fig. 73. It is usually desirable to head-in young trees for two or three years after planting; it makes them stockier.

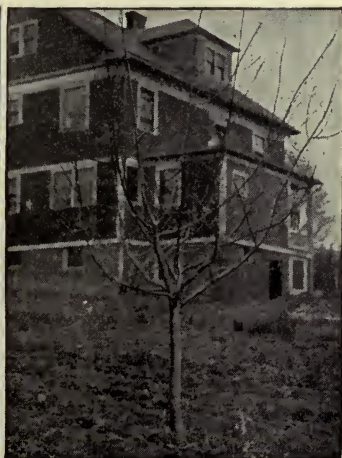


Fig. 74. Improperly trained. The limbs start too close together. The first big crop will split off some of them.

makes the new branches grow very vigorously, but, as the fruit in grapes is borne on the new wood, this is very desirable. (See ¶ 157.)

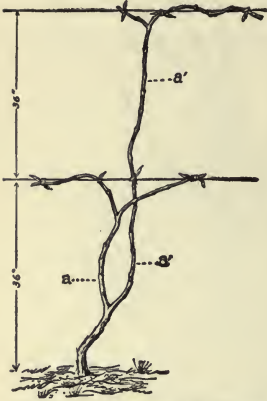


Fig. 75. Y-system of pruning and training grapes.

The growth of the vine for the first season after transplanting is cut back to a single shoot, for at least four or five feet. This is tied up to the central wire and forms the permanent stock, or stem. In pruning, after the first year, from two to four arms, or branches, are left to produce the bearing wood. The number and length of the arms will vary with the vigor of the plants. Weak-growing vines are usually left with only two or three arms.

The most desirable form of grape trellis is that shown in Fig. 76, known as the Canopy, or Munson trellis. This kind of trellis allows more leaves to be exposed to the light, and gives more color and flavor to the fruit.



Fig. 76. Munson system of training and trellising grapes.

CHAPTER XIX

PROPAGATION OF PLANTS

190. How Plants Propagate. Plants propagate naturally by seeds and by the formation of special parts, which become separated and independent of the parent plant, as bulbs in onions, stolons or runners in strawberries, tubers (thickened stems) in Irish potatoes, and by roots, as in the sweet potatoes, and in many other special ways. These are natural methods of multiplication, and take place without man's assistance. Often man provides the conditions which favor multiplication in these ways. We have already mentioned the important conditions to be controlled in causing the embryo plants of sprouting seeds to grow. The other natural processes of multiplication, i. e., by tubers, bulbs, etc., are matters of every-day knowledge, and are used for propagating a variety of plants. We speak of the former as propagation by *seedage*, and the latter as propagation by *division*.

191. Seedage. In preparing land for seeds, it is not sufficient that the seed-bed provide simply the conditions favorable for germination, but should be such as is demanded by the nature and peculiarities of the plant. Thorough and deep pulverization is desirable for all kinds of plants. Make a good seed-bed. It should be done long enough before planting to allow for a thorough settling of the sub-surface soil, for many crops, such as wheat, corn, and other grains, do best on a settled seed-bed. In planting, therefore, it is necessary to know the

special requirements of the crop. Quick-growing annuals and root-crops do best on a very loose seed-bed. Sugar beets become fibrous, and may be pushed out of the ground if the roots reach a hard subsoil. The depth of covering the seeds often has a great influence not only on the promptness of germination, but, also, on the fruitfulness of the crop. The distance between the seeds must be such that there is proper room for the development to the size desired at maturity, or for transplanting.*

192. Propagation by Seedage and by Division Compared. The embryos in seeds are formed by the union of the nuclei of pollen and egg-cells, each from different individuals. In division, the new individual is formed from a part of the original plant, and, therefore, has only the characters of the original plant, that is, it is just like the original plant. Seed-propagated plants often partake of the characters of two individuals. This explains why seed-propagated plants are more variable than those propagated by division. For illustration, we may use blackberries. Fig. 77 shows the forms of the leaves of a number of blackberry plants grown by Luther Burbank from seeds of a single plant. Not all seeds are so variable as the example given, but they are, in most cases, variable, and the differences are only of degree. *Therefore, in order to make sure of propagating the desirable qualities of some particular individual, resort is had to propagation by division.*

193. Propagation by Division may be by some of the

*NOTE.—It is not advisable to discuss the needs of particular crops in a general text-book, but a number of interesting comparisons may be made in this connection by comparing (1) the season of seedage; (2) depth of planting and size of seed; (3) how the depth of planting affects the potato crop; (4) the duration of the roots in the soil; (5) surface feeding and deep-feeding or tap-rooted plants.



Fig. 77. Variation in leaves of hybrid blackberries, all from the seed of one plant. The stems of the plants varied just as much in shape, size and color. The parents of these forms were Oregon Evergreen and Lawton. Many new forms are produced in this way. A thousand or more forms may be produced and discarded without finding even one having real merit. (¶ 212.) After photograph by Luther Burbank.

natural processes, such as mentioned in paragraph 190, or by artificial processes, such as by layers or buds. The process of propagating by cuttings is known as cutting propagation. That by layers, as layering; that by inserted scions, as grafting; and that by inserted buds, as budding. They may be termed respectively, cuttage, layerage, graftage, and buddage.

194. Layerage. When a branch or part is caused to form roots, and then severed from the parent plant, the plant produced is a layer. Fig. 78 shows how a vine of

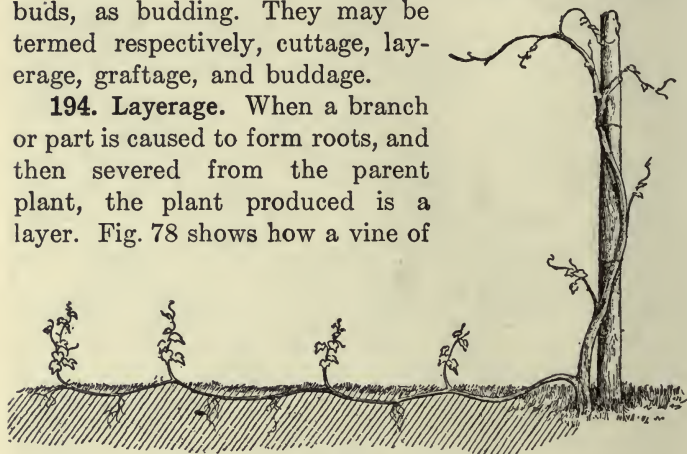


Fig. 78. Propagating grapes by layering.

the grape may be bent down, and covered at intervals with moist soil. Roots form at the nodes. (See ¶ 68.) After these roots are sufficiently abundant, the vine may be cut into pieces, each piece having roots, and each planted in a new place as a complete plant. Layering is used to propagate grapes, raspberries, dewberries, and many other plants. Strawberries, dewberries, blackcap raspberries, and many grasses, such as Bermuda grass, Johnson grass, some of the Musquite grasses, white clover, and some varieties of sweet potatoes, naturally multiply by their prostrate stems, taking root at every node; and man, in practical agriculture,

greatly aids it by better preparing the soil. There are many plants that do not often multiply in this way, but will readily do so if their bodies or branches be bent down to the ground and covered with mellow soil.

195. Cuttage. Rooted cuttings are parts of either stems or roots (or leaves, in some cases), cut into small pieces and kept under proper conditions until the formation of roots and shoots has taken place. Cuttings of some kinds of plants put out roots very readily, as willow, dogwood, roses, grapes, some kinds of plums, and berry plants. Cuttings may be made from dormant or green growing shoots. Geraniums are propagated from green cuttings. Green cuttings should be kept moist at all times.

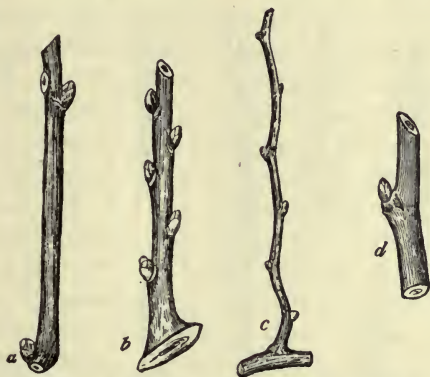


Fig. 79. Cuttings: *a*, simple cutting; *b*, heel cutting; *c*, mallet cutting; *d*, single-eye cutting.

196. Buddage. The callus-tissue of one plant may unite with the callus-tissue of another plant, if the two plants are of the same kind. Apple may be made to unite with apple; peach with peach; but not peach with apple. However, peach will unite with plum, because peach and plum are closely related. In budding we have two parts: (1) A *bud* of the kind or variety to be propagated, and (2) a *stock*. The stock may be a rooted cutting or a seedling. In the common "T"-budding, a sharp

knife is used to make a "T"-like slit through the bark, as shown in Fig. 80D. The corners may be raised and a bud, cut as shown at *E*, placed under the edges of the bark of the stock, as shown at *G*. The cambium layer of the bud is left in contact with the cambium layer of the stock. The wound is wrapped with soft twine, such as cotton yarn, or other suitable material, to hold the

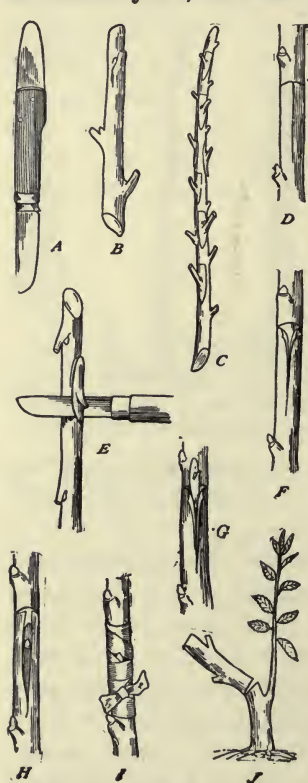


Fig. 80. Steps in propagating plants by budding

edges of the bark down and keep the bud from drying out as at *I*. After a week or ten days, depending on the condition of the shoot, the bud will be grown to the stock, if the work has been properly done. In this way we may cause one variety of plant to unite with another. Budding is easiest made and most likely to be successful if made while the stock is growing rapidly, or when the bark "slips," as it is called.

197. Later Care of the Bud. After the bud has united with the stock, there is still much to be done before we have a new plant. The strings are removed when the bud has united with the stock. The later condition is shown by the bud remaining green and plump. After

a week to ten days, or when the string begins to be overgrown, it should be cut and removed. The next step is to force the bud into growth. This may be done immediately, as in "force budding," or left until the following spring, when the top of the stock is cut off just above the inserted bud. This causes all the buds below to swell and many to form shoots. All the new sprouts except the one from the inserted bud should be rubbed off when they attain three to five inches in length. This causes the new shoot to grow very rapidly. Many persons leave a foot of stock stem to protect the young shoot. As soon as the latter is thoroughly established, the stock is pruned close down, as shown in Fig. 80J. The final result is that we have a stem of one variety growing on a common seedling stock. One may propagate millions of Elberta, or other variety of peach trees in this way, and every tree will bear peaches just like the parent variety. The great value of propagation by budding is obvious. Choice varieties of peaches, plums and apricots are propagated by budding. It is often used for pears, apples, roses, and many other kinds of plants. Special methods of budding are used for pecans and other hardwood trees.

198. Graftage. In propagation by grafting, two parts are used, as in budding. One we call a stock, or root, and the other the *scion*, the latter coming from the plant to be propagated. The scion usually consists of a short piece of stem. In making the *cleft-graft*, the stock is split open smoothly, as shown in Fig. 81A. The lower end of the scion having been trimmed to a wedge is inserted as shown at A. Care should be taken to see that the cambium layer of stock and scion coincide, at least on one side. (Fig. 81C.) The graft is now wrapped

with waxed cloth to prevent drying out. The two layers of cambium grow and unite, and the scion grows out into a vigorous shoot. Cleft-grafting is used in propagating

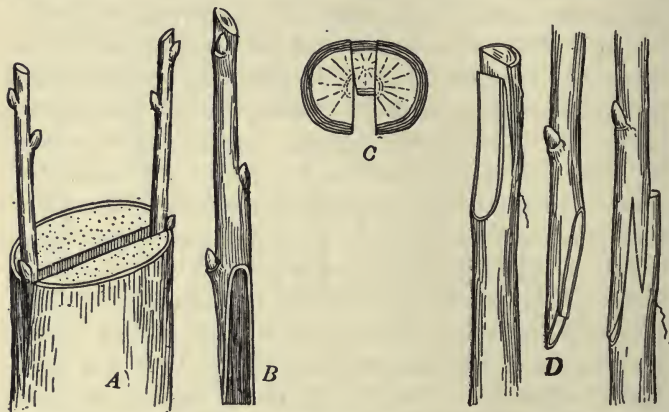


Fig. 81. Steps in propagating by graftage. A, B, and C, details of cleft graft; D, same for tongue graft.

many kinds of plants, such as apples, pears, peaches, etc. If the graft is made below the ground on a rooted stock it is not necessary to wrap with waxed cloth. The moist soil, pressed firmly about the union, prevents drying out.

199. In Tongue Grafting, we make a sloping cut on both scion and stock. (Fig. 81D.) The tongue of one is slipped into the cleft of the other, care being taken to have the cambium layers together, at least on one side. In piece-root grafting, as is usual with pears and apples, the graft is wrapped to secure the two pieces in an unmovable union until the callus growth has had time to unite. They may be prevented from drying out by storing in moist sand or sawdust. It is usual to make the grafts during the winter months and plant them in the nursery rows early in the spring. (Fig. 82.)

200. Care of Buds and Grafts. There are many special ways of budding and grafting. All depend on the property of callus-tissue of two different plants to form a close living union. In making the cuts, nothing but the sharpest of knives should be used. Dull knives produce such mutilation that the cambium does not grow out and form the callus-tissue promptly, and, as a result, the graft or bud fails "to take." The dormant buds on the stock are inclined to form vigorous-growing sprouts, but should be rubbed off as explained in ¶ 197.

201. Transplanting Nursery Trees. Nursery trees, whether propagated from seeds, cuttings, buds, or grafts, are removed from the nursery rows and trans-

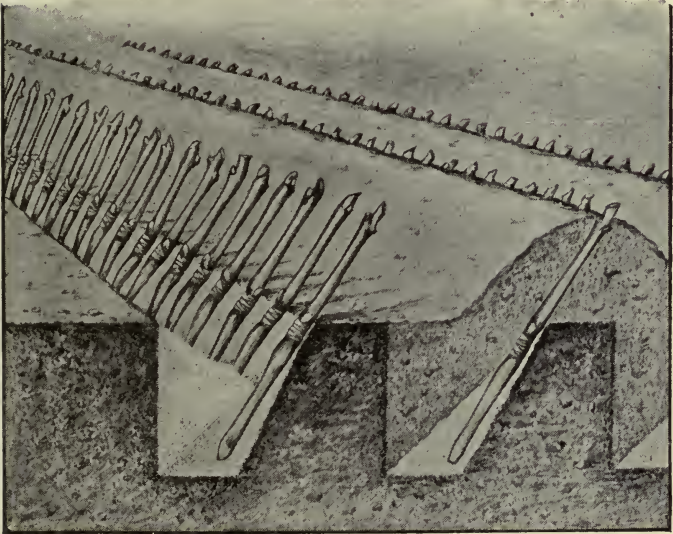


Fig. 82. Grafted cuttings set in nursery row.

planted in orchards. In removing nursery stock, many of the roots are necessarily cut short. In transplanting, the ends of all bruised or mutilated roots should be cut off smoothly and the top cut back to keep it in balance with the roots. Fig. 63 shows a one-year-old budded peach tree trimmed ready for transplanting. The young trees should be put into good-sized holes and loose, moist soil worked in around the roots, and tramped just sufficiently to hold the young tree in position. In transporting nursery stock, the roots should never be allowed to become dry. When trees are received from the nursery they should be set in trenches and dirt thrown over the roots. If the soil is not moist it will be well to apply water freely.

It will usually be much better if young orchard trees are set in the place they are to grow in the fall months. They will thus have plenty of time to form new roots. Fall-planted trees usually put out their leaves earlier in the spring than trees planted in late winter. Young orchard trees should be especially well cared for during the first season after transplanting. (See ¶ 61.)

CHAPTER XX

IMPROVING PLANTS AND SEEDS

202. Domesticated Plants. The cultivated plants were originally wild sorts. Some of them have been cultivated so long and so improved by man's care that the original or wild form is not certainly recognized, such as wheat, potato, onion, cabbage, etc. Other sorts have been brought into cultivation in comparatively recent times, and the original wild form is well known, as the tomato, carrot, chrysanthemum. Cultivated forms are vastly superior to the wild forms. The strawberries of our gardens are more palatable and productive than the wild sorts. The cultivated tomato is much larger and firmer than the original wild form. Wherever a plant has been long under cultivation it has been greatly modified. We may ask, "How are these improvements secured?"

203. Variation in Plants is the starting point for improvement. Scientists have a theory that all the plant and animal forms descended from some common ancestor. This theory of the origin of living forms, called the "theory of evolution," finds its support in the similarity of many forms, suggesting relationship, and the further fact that, through natural variation, new forms are constantly



Fig. 83. Old-time and new-time forms of tomato. After Bailey.

coming into existence. Plant-breeders try to cause variations.

204. Fixing Variations. Variations in cultivated plants more often resemble earlier and less valuable forms. Where improvement is desired, great numbers of individuals should be observed and a few of the most promising saved for seed. This is called *selection*. When seeds are saved from individual plants with desirable

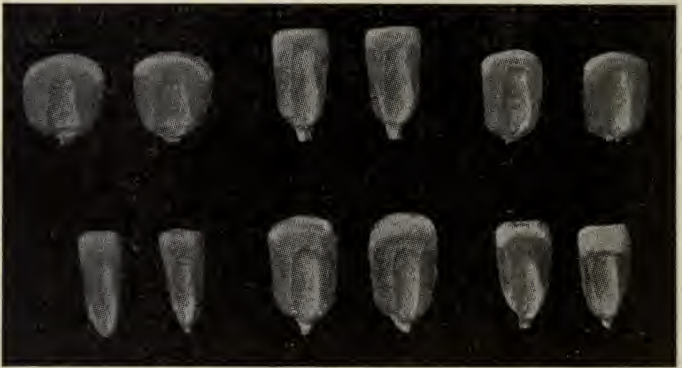


Fig. 84. A chance for selection. The two kernels in the center are the best. The two outside grains at each end of the upper row are too short. The two outside ones in the lower row are too pointed at the tip, showing lack of vitality.

characters, they should be planted away from other plants of the same kind. Usually, only a few specimens of the progeny will retain the good qualities of the parent. Selections should again be made. By repeated selection, a large per cent may be made to "come true to seed." This is called "fixing the type." Where the crop is grown for seed, the field should be gone over and all plants that are noticeably inferior or not true to type should be removed. This is what the seed-grower calls "rogueing."

205. "Natural Selection." The original wild species owe their form and habits to the continuous selections which wild nature makes. Wild plants must grow in competition with other plants and struggle with them for the conditions necessary for growth and the preservation of their seeds. The size, form and character of the leaves, stems, flowers, fruits and seeds, are all important features in the struggles for nature's favors.

206. No Improvement Without Variation. No two plants are exactly alike. The offspring from the same individual are not alike. This is the fact of "variation." In some forms the variations are more obvious than in others. As a rule, variations in wild plants are less frequent than in cultivated forms. Variations may be desirable or undesirable and progress comes from propagating only the best selections. Improvements could not be made if all individuals were alike.

207. Variations Are Not Permanent. The Concord grape is a variation of the wild fox grape of Massachusetts, discovered by E. W. Bull about 1850. It has been propagated by division ever since and is still the same grape, because our Concord grape-vines of today are only parts of the original plant. However, when the seeds of Concord grapes are grown, we get the original wild fox grapes. Many such seedlings have been grown, but none have yet been secured that are the same as the parent vine, although some of them are very nearly like it. DeVries had a variety of corn, the ears of which had eight to twenty-two rows of grains. The average number of rows was between twelve and fourteen. He planted an ear having sixteen rows and found the average in the crop to be fifteen rows per ear. He then planted some ears having twenty rows and continued this for

six generations. At the end of this time the average of the variety was twenty rows, whereas it had originally been only thirteen. The lowest number of rows on any ear was twelve and the highest twenty-eight, a number that had never been observed in the parent variety. The average and the actual number of rows had been greatly increased by continuous selection through six years; yet, when left for three years without selection, the average number of rows was back to thirteen. Other instances might be mentioned, showing the inconstancy of varieties propagated from seed.

208. Perpetuating Desirable Variations. How may a desirable variation be perpetuated? There are two ways: (a) *Propagating the Plant by Division.* (b) *By Repeated Selection toward an Ideal Type.* Many kinds of plants are more conveniently propagated from seed, such as the grains, cotton, garden vegetables, and the like. We have seen how the number of rows of grains on an ear of corn was increased. Had the selections been continued for ten or more years, the new characters would have been more fixed.

(c) *Special Methods.* In addition to continual selection, plant-breeders sometimes resort to inbreeding to fix variations. Plants that normally inbreed, like oats, wheat, cotton, and others, are much less variable than kinds that are normally cross-fertilized, as corn.

209. How to Stimulate Variation. While seed-propagated plants are variable, in fact too much so for the average grower, the plant-breeder desires to bring about the most decided variations possible in the hope that some form of unusual value may be secured. The means usually relied upon are:

(a) *Intensive Culture.* Plants grown under the most

favorable conditions are thought to produce a more variable offspring than wild or uncultivated plants.

(b) *By Hybridizing Dissimilar Forms*, such as different varieties, or species. Many valuable varieties of fruits have been secured by cross-fertilizing individuals belonging to two different species.

We have already noticed the variations in hybrid blackberries (§ 192). As a rule, the more dissimilar the parents, the greater are the variations in the seedlings. In choosing parents for hybrids, it is well to consider the characters of each; for it is possible, though often quite difficult, to combine the good qualities of two forms in a single individual.

210. Some Notable Results. Professor Munson found that the varieties of the wine grapes, grown with such success in Europe, and the fox grapes, in the eastern United States, were not suited to the climate of the Southwest. He sought to combine the hardiness of the native wild grapes of Texas with the fine flavor and fruitfulness of the foreign species by hybridizing. Many valuable varieties of grapes well suited to Texas conditions have been produced in this way. Some of the most popular are the Carman, Fern, Muench, and America, each having one-half of the native Post-oak grape blood. The Kieffer pear is a hybrid between the Bartlett and Chinese Sand pears. The Bartlett pear has a delightful flavor but often suffers from blight. The Sand pears are poor in flavor but quite hardy and fruitful. Many fine varieties of plums, blackberries and dewberries have been produced by hybridization.

211. Hybridization is accomplished by placing the pollen of one variety or species upon the stigma of another. To prevent self-pollination, the anthers should

be removed before the pollen is mature. (Fig. 85.) In the flowers of wheat, oats, peas, and some grapes, pollination takes place before the flowers open; hence, in such plants it is necessary to remove the anthers very early.



Fig. 85. Buds or "squares" of cotton. 1. Flower-bud nearly ready to open; 2, parts removed to expose the stamens; 3, stamens removed to prevent self-pollination. After Hartley, United States Department of Agriculture.

After the anthers have been removed, the stigma should be protected from chance-flying pollen by covering the flower with a paper bag. The sack may be removed when the pollen is to be placed on the stigma. The latter may be accomplished by a clean, moistened finger, camel's-hair brush, or other means suited to the plants in hand. For success in artificial cross-pollination, one should fully understand the structure and habits of flowers in both parents.

212. The Hybrid Seedlings. The seedlings from hybrid seed should be closely observed. Out of a great number of individuals, only a few, possibly none, will possess the desired characters. Even though none are found, it is often desirable to grow their seed in the same way for the desired form may appear in the second generation.

When a specimen is found having merit, it should be given special care and properly propagated (§ 208). When a new form is secured and has its characters so fixed until they "come true," it is called a variety.

213. Examples of the Value of New Varieties. The improvement of our cultivated plants has been gradual because but few men have made it a business to look for and select out the best forms. Many men, however, have secured decided results in a few years by following scientific methods. The work of Professor Munson has already been mentioned. Hays was able to secure a strain of Minnesota blue-stem wheat that produced five bushels more per acre. When wheat is worth 80 cents, such seed represents a superior earning value of \$4 per acre. Many other examples of the great value



Taylor

Iron

Black

Fig. 86. Iron cowpea vs. Black and Taylor, showing comparative resistance to the Wilt and Root Knot. From Bulletin United States Department of Agriculture.

of propagating seed from desirable individuals might be given. The old varieties have, in many cases, been crowded out by the introduction of new and better forms. Special attention should be called to the Elberta peach, many excellent varieties of grapes, Austin dewberry, Gonzales and other varieties of plums, Triumph cotton, and other forms that have added immensely to the value of the harvests of the world's staples. A variety of the cowpea has been discovered that is not only resistant to "wilt," but to the little worm which causes the formation of knots on the roots of other varieties. (Fig. 86.)

213a. **Selecting Seed Oats.*** Suppose that it is desired to improve the quality and yielding power of oats. The first question to be answered is, "What quality has the oat that makes it valued? For what may the oat plant be used, and what does it supply?" In the South it is sown in the fall and the field is used for winter grazing. It makes a crop of grain which is thrashed and the straw and the grain are both used. The grain has most value so that in selecting oats we usually select for fine grain.

Next let us find out what an oat grain is. If we carefully hull an oat grain we find a hull composed of two or more pieces, and a true seed. If we examine a number of large grains we shall find that the large grain usually has a large seed. In selecting the seed then we will select the large grain. Now secure a bundle of oats harvested and bound just as they come from the fields. Let each student take a dozen heads as they come, spread them out on a table and note

*The foregoing outline of the process of selecting seed oats and suggestions for testing the qualities in the plants of the progeny are given merely to illustrate the more fundamental problems of seed improvement, and the common crops or garden plants. They may be carried out by any energetic boy or girl in a corner of the garden with noticeable results in improving the plants. As an exercise for training the mind in observation, comparison, discrimination, and test of ideas, it will prove highly satisfactory to the teacher from the viewpoint of culture training as well as a practical study in "the relation values." Oats have been selected because they may be grown and matured during the school year. Local conditions may suggest other material. Some consideration should be given to the more important crops of the community, such as corn, cotton, kafir corn, sugar-cane, rice, and the various kinds of fruits.

the differences in the heads. Now thresh out each head separately and put the grains from each head in a small bottle. Note differences in color, size, shape, etc. What sorts do you consider the best oats? Why? Save the best four and take home and plant one seed at a time in drills one foot apart, and one foot in the drill. Plant seeds from each head separately, so that if they grow differently it may be noticed. Compare the quality of the crop from the four different heads. If the school has a school garden they may be planted there.

214. Effect of Cultivation. Cultivated plants are shielded from competition with other plants; they are planted in prepared ground, given plenty of space, and protected from many destructive agencies; their seeds are harvested, stored, and throughout the life of the plant they are given favorable opportunity to make vigorous growth. Cultivated plants are selected, not for their ability to propagate under unfavorable conditions, but because of their power to grow and fruit under favorable conditions. Wild plants do better under cultivation, but not in the same degree that improved varieties do. In selecting seeds for propagation, preference should be given to the forms which show the greatest yield under favorable but practical conditions. The local conditions, whether due to peculiarities of climate or conditions produced by culture, often affect the result quite as much, possibly more, than the kind of seed. A variety may yield very satisfactory harvests in one place, and yet be quite unsuited to other localities or uses. It has been found to be quite generally true that when equal care is given to seed selection home-grown seeds are better yielders.

CHAPTER XXI

FUNGUS DISEASES OF PLANTS

215. Many plants of the farm and garden are subject to attack by various kinds of minute plants, known as fungi. The "rusts" of small grains, plum trees and cotton, are familiar examples. Also, the "mildew" of grapes and roses. These fungi are thread-like plants. Some form their thread-like bodies *inside* of the plant tissues, such as the "smuts" and "rusts." (Fig. 87.) Other forms, like the mildew, grow on the surface of the



Fig. 87. A, head of oats affected with smut, the chaff being only partially destroyed; B, head of oats decidedly smutty, but having the chaff only partially destroyed; C, final stage of oat smut, showing condition at harvest time

leaves and stems, but send little root-like branches (Fig. 89) into the plant tissue to absorb its substance. Another class of fungi, known as bacteria, never form "threads," or *hyphæ*, as they are called by the botanist, but only cells. Some species of bacteria cause disease. The cells are formed *inside* of the plant body.

216. How Fungus Plants Get Their Food. Fungi do not have the green chlorophyll (§ 48),

and, therefore, can not make their food like the algæ and the higher green plants. They are called dependent plants. There are many kinds. Plants like the fungi are thought by scientists to be greatly changed algæ that have lost

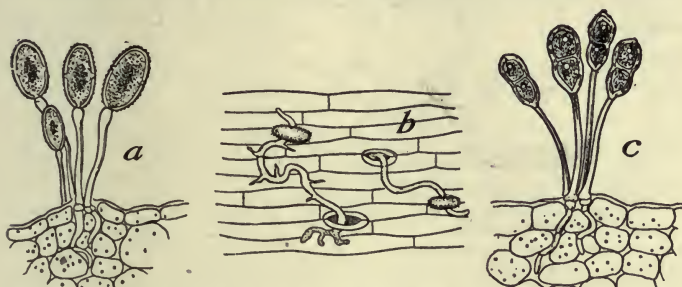


Fig. 88. Spores, or seeds, of the fungus producing the "rust" of wheat. A, summer spores, or "red rust" stage; B, same germinating on surface of leaf; C, autumn spores, or "black rust" stage. Greatly magnified.

the power of carbon assimilation, and are, therefore, dependent on host plants to supply the food they need. They are called independent plants. Many higher plants are dependent in the same way, such as the dodder, or "love vine." They grow under many conditions, but all must get their food from plant or animal substance. Species that get their food from living plants or animals are called *parasites*. Those that get their food from dead plant or animal remains are called *saprophytes*. Some species of fungi may get their food from either living or dead organisms. The red or black powdery mass which we call "rust" is only a mass of *spores* (one-celled seeds) of the fungus causing the disease. The body of the plant exists as a lot of threads inside of the host-plant and is not visible to the eye. When magnified by the microscope, these fine hyphæ may be plainly seen.

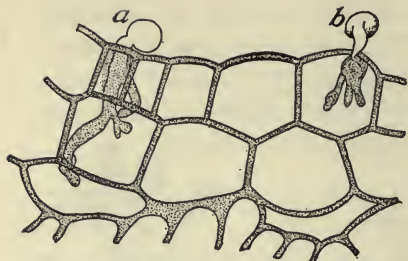


Fig. 89. Germinating spores of the "Potato Blight" fungus. Cross section through a portion of a stalk. Two germinating spores (*a, b*) piercing the epidermis, and the threads penetrating the cells of the leaf. Highly magnified.

thread soon enters the plant and absorbs the moisture and food substance of the potato leaf. It soon forms a crop of spores, sometimes in only a few days. These spores are blown to other plants, and soon a whole field will be blighted by the fungus. Most species of fungi grow on only one kind of plant. The fungus that causes grape mildew (Fig. 90) does not grow on any other kind of plants but grapes. The fungus that causes the blasting of the ears and tassels of corn (corn smut) grows only on corn. The fungus that causes the smut of oats never attacks corn. However, the fungus that produces the rust on grains also attacks

217. How Fungi Propagate. Fungi propagate by minute cells, called *spores*. They correspond to seeds of higher plants. They require the same conditions for germination as seeds. Fig. 89 shows a spore of the potato blight germinating on a leaf. The first



Fig. 90. Downy mildew of grape (*Plasmopora viticola*), showing tuft of gonidiophores bearing gonidia, also intercellular mycelium. After Millardet.

barberry bushes. A number of fungi known as "rusts" have more than one host-plant. The yellow rust of apple leaves is the same fungus that produces the so-called cedar apples on cedar trees.

218. Not All Fungi Cause Disease. Some fungi are very useful, like the little bacteria that gather the free nitrogen of the air for beans and clover plants; the yeast, used in making bread, and in making wines and beers. Some fungi are quite large, as the mushrooms and puff-balls. Certain kinds are highly esteemed as table delicacies, and are cultivated. Some species of mushrooms should not be eaten because they are poisonous.

219. Preventing Fungus Diseases. There is no cure for the fungus diseases in plants. Prevention is the only safeguard against loss from parasitic fungi. This is accomplished in four ways:

(a) *Treating the Seeds* with substances that destroy the disease-causing germs, as scab in potatoes, smut in oats and wheat.

(b) *Using Resistant Varieties.* Not all plants are equally subject to the attacks of parasitic fungi. Some varieties are much less injured than others. (Fig. 86.) Many varieties of cultivated plants owe their value to their power to resist disease.

(c) *Sanitation.* When crops are subject to a particular disease, all the dead parts, trash and litter that harbor the spores, should be gathered up and burned.

(d) *By Using Fungicides.* Fungi are poisoned by extremely small amounts of copper salts, or sulphur in some cases, while green plants are not affected by small amounts. Preparations of copper salts in water are, therefore, used to spray plants to protect them from attacks of fungi. A compound of copper sulphate (blue



Fig. 91. The "brown rot" of plums and peaches leaves "mummies" on the trees.



Fig. 92. Black rot of grape may be prevented by timely use of Bordeaux mixture.

vitriol) known as Bordeaux mixture (given in the Appendix) is most often used. The plants are sprayed with a very dilute solution, so that a thin film of the poison covers the leaves, stems, buds, and fruit of the plant. Spores on the surface of thoroughly sprayed plants are killed, as likewise others that fall on the plants. It is often necessary to make several applications, to replace the film of spray washed away by rains. Sulphur, formaldehyde, and other substances, are used for special diseases.

220. General Methods in Using Sprays. Where efforts are made to prevent the attacks of fungi by sprays, it is important to know how and when infection takes place. No general rules can be given. The time and manner of applying the fungicide must be suited to the conditions peculiar to the

disease. The agricultural experiment station bulletins and special books on spraying will supply full information.

221. Diseases of Orchard Fruits, such as brown rot of peaches and plums (Fig. 91); mildew and black-rot of grapes (Fig. 92) and other common diseases are controlled by spraying with Bordeaux mixture. The first



Fig. 93. The apple scab may be prevented by spraying.
From Cornell University Junior Naturalist.

spraying should be before the buds swell, and repeated every few weeks thereafter until the crop is safe.

222. Grain Smuts. The smuts of oats and wheat (Fig. 87) may be prevented by treating the seed before planting. The spores become lodged on the grain on the hull or fine hairs. When the seeds are planted, the spores germinate with the seed. It is peculiar, but true, that this fungus can infect the plant only in the seedling stage. Therefore, it is plain that, to prevent the blasting of the oats by smut, we must destroy the smut spores on the seed before planting. This may be done without injury to the grain by treating the seeds with

dilute solutions of formaldehyde, or other preparations.

222a. Preventing Smuts in Grain Crops. Full directions for treating small grains to prevent smut may be obtained from Farmers' Bulletin No. 507, U. S. Department of Agriculture, or other bulletins from your State Experiment Station. Other bulletins give information on the control of smut of sorghum and other crops. Every class in agriculture should make tests on smut prevention.

223. Potato Scab may be prevented by soaking the seed potatoes in a two- or three-per-cent solution of formaldehyde for one or two hours. This destroys the fungus in the scabs and cracks on the potatoes.

224. Cotton-root Rot is a serious disease of cotton on heavy clay lands. The disease does not attack cotton on loose, sandy soils. This fact has suggested the practice of early and deep breaking of land to prevent the growth of the fungus. Results are favorable to the practice. Rotation is also a means of holding this disease under control. The destructive effects of the cotton-root-rot fungus is often confused with damage due to alkali. The soft, spongy condition of the roots of plants killed by this fungus is very characteristic. This fungus also attacks okra, orchard trees, shade trees, etc., in fact nearly all classes of plants except members of the grass family, such as corn, small grains, sorghum, etc. It is plain therefore that, if such plants as the small grains, corn, etc., are grown on the land, the fungus will be starved out, so that cotton or other susceptible plants may be again grown. It is important that weeds that might harbor the fungus should be destroyed. Fields will rarely become seriously infested with this fungus if proper rotations are made. No variety of cotton has yet been discovered that resists the attacks of this fungus.

CHAPTER XXII

INSECTS ON THE FARM

225. There are a great many kinds of insects found on the farm, many of them useful, while other kinds are injurious because they feed on plants, stored products, and domestic animals, according to the habits of the pest in each case, and even our own comfort and health are affected by various forms of these creatures. Not all the small animals are properly called insects. Insects have just six legs, and their bodies are made up of three parts that may be easily distinguished: First, the head; second, the thorax, or middle part; and third, the abdomen. The spiders, ticks, mites and scorpions have eight legs and never have wings.

The common sow-bug has fourteen legs and is classed with the crabs and craw-fish rather than true insects.

226. Changes of Form in the Growth of Insects. Nearly all species of insects have four forms in passing from the egg to the mature insect. It is like the story of

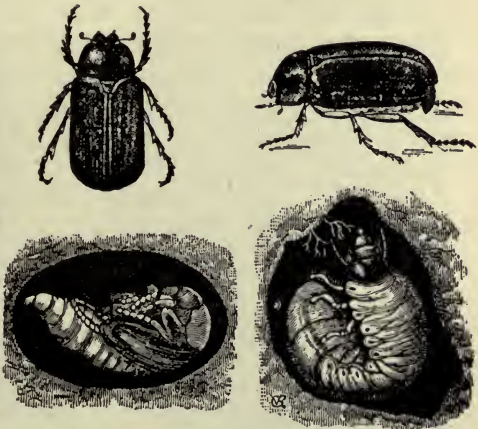


Fig. 94. Stages in the life history of the June-bug. After Howard Division of Entomology, United States Department of Agriculture.

"The House that Jack Built." The female lays the egg; the egg hatches into the larva (caterpillar, grub, or maggot); the larva feeds and grows and turns into a chrysalis, or pupa, and from this pupa comes the adult insect. Take the common May-beetle, or June-bug as an example. (Fig. 94.) The adult lays the egg among grass roots during spring or summer. From this then hatches a small larva (white grub, or "grub-worm"), which feeds on the roots in the soil. It grows rapidly, and, at the end of the second season, goes into a dormant state and changes into a pupa, and, at the end of two years, emerges from the ground as a May-beetle, or June-bug. In the larval stage, the June-bug often does much damage to the roots of grasses, corn, wheat and garden plants, while the adult feeds on the leaves of trees—often fruit trees.

The caterpillar stage in insect development is quite



Fig. 95. Plum curculio. A, larva inside of peach; B, mature insect depositing egg. After Quaintance, United States Department of Agriculture.

unlike the mature butterfly stage. Again, only the closest watching of the life history of the "wiggle-tail" convinces us that it is a mosquito in another form. The little "worm" (larva), found in the plum, is quite different from the shy curculio beetle that laid the egg. (Fig. 95.) Grasshoppers, squash bugs and crickets are examples of insects which attain maturity by gradual growth without distinct stages. (See Fig. 99.)

227. How Insects Differ from Other Animals. Insects, like the frogs and snakes, are cold-blooded animals. The temperature of their bodies changes with that of the air or water, in whichever they happen to be. When cold weather comes, many kinds find shelter under fallen leaves, sticks, or may burrow into the ground and there remain quiet until warm weather returns. This way of passing the winter is called *hibernation*. While hibernating, they may be frozen stiff, or the eggs and larvæ may be frozen; but when the weather becomes favorable, many kinds will move about just as lively as ever. Severe freezing may kill some, but many will survive. The propagation of some sorts is dependent on the ability of the eggs to withstand the winter. Higher animals have the bony skeleton inside of the body, but insects have the hard bony part on the outside. The muscles of insects are attached to the outer body wall and not to internal bones, as in other animals. Insects do not breathe through a mouth, but have little breathing pores along the sides of the body. The nerves of the insect that detect odors and guide it to its kind and food are usually in the little "feelers," or *antennæ*, or sometimes in the segments of the legs.

Some species of insects die soon after laying eggs, often before the eggs hatch, as the tent caterpillar; others

may live on through a longer period, laying eggs continuously, as in the case of the cotton boll-weevil.

228. The Food of Insects. Insects are very peculiar about the food they eat. Just like the many species of parasitic fungi, each species feeds, usually, on just one kind of plant or animal, or on closely related plants or animals. In such cases we speak of the plant as the "host" for a particular insect. The Colorado potato beetle



Fig. 96. Colorado potato beetle. *a*, eggs; *b*, larvæ; *c*, mature beetle.

After Riley.

beetle (Fig. 96) is a native of the West, living on the western species of nightshades. When the Irish potato was introduced, it found a plant closely akin to its regular food plants, and on which it thrives to such an extent that it takes its name from the new host-plant. Sometimes there is a wide difference in the kinship of the host-plants. The feeding habits of the "boll-worm" of cotton, or the "ear-worm" of corn, the same insect in both cases (Figs. 97 and 103), is a striking example of a form which feeds on a number of different kinds of plants. When

insects do not find acceptable food-plants they die. Many insects are exclusively flesh-eating, such as the common "doodle-bugs," wasps, lady-bugs, and many species of wood ants. Mosquitos are a common form of blood-sucking insects. Many parasites are solely responsible for the spread of diseases. The ticks on cattle, which are somewhat related to true insects, are carriers of disease. Cattle do not have the splenic fever (sometimes called Texas fever) except when the germs are carried by ticks that bite them. The common bee lives on the nectar and pollen of flowers. It is not the only insect that lives on nectar. Most species of butterflies, moths, bumblebees, etc., are nectar-loving insects. We have already learned that these insects are very useful in bringing about the pollination of flowers.

229. The Feeding Habits of Different Stages. The depredations upon plants and animals are made in various ways. Often the

immature stages are more destructive than the adult. Most frequently it is the larval stage (caterpillar, grub, maggot) that depredate upon the plants. The Colorado potato-bug lays its eggs on the leaves. The young larvæ are hatched out, therefore, right at the breakfast table. In the caterpillar stage, some species of insects occur in great numbers, and they are, hence, often spoken of as



Fig. 97. Corn ear-worm or cotton boll-worm. After Quaintance, Bureau of Entomology, United States Department of Agriculture.

"army worms," of which the "cotton army worm" is a common example in the South. Some caterpillars, known as cutworms, work only at night. When daylight

comes, they are concealed under clods, and any trash that may be present. They are called "cutworms" because they have a habit of cutting off young plants near the ground. They are the caterpillar stage of several kinds of night-flying moths. (Fig. 98.)

Thus we see that there are some insects which are perfectly harmless in the adult stage, but



Fig. 98. Cutworm and moth. After Howard. Bureau of Entomology, United States, Department of Agriculture.

whose larvæ do great damage. The pupal stage is inactive, and requires no food.

230. How Insects Get Their Food. (a) *By Living inside the Plant. Internal Feeders.* It quite often happens that the egg is deposited inside of some part of the plant and the larva develops there, as in the case of the larva of the plum gouger. As the larva is inside of the plant (Fig. 95), it cannot be destroyed by any of the sprays, and, in such cases, effort is made to catch and destroy the adults before the eggs are laid.

(b) *External Feeders.* Insects that feed directly on the leaves, fruits, etc., have mouth parts that are provided with scissors-like jaws by which their food is cut from the plant. To destroy insects that feed in this way, it is sufficient to cover the leaves with some suitable

arsenic compound by sprays. When they eat the leaves, they consume enough of the poison to induce their death. Paris green, London purple, and arsenate of lead are the most usual poisons. Grasshoppers, potato bugs and army worms may be killed in this way. In some portions of Texas there are leaf-cutting ants, which attack trees and cut and carry off nearly all the leaves. These

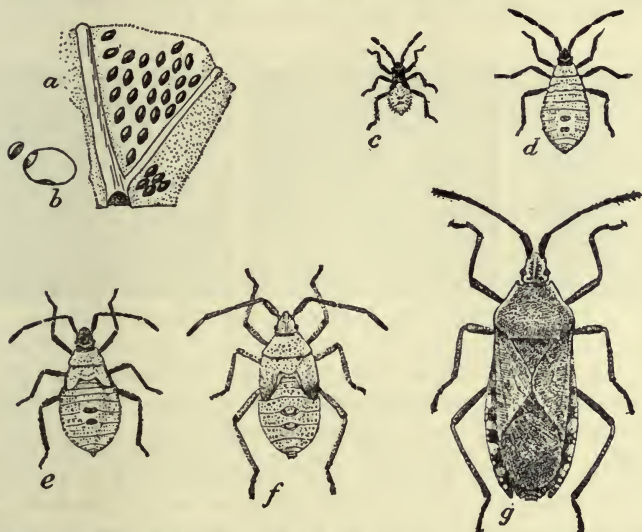


Fig. 99. Squash bug. A, eggs on leaf; b, egg-shell; c, d, e, f, nymphs; g, adult. After Chittenden. Bureau of Entomology, U. S. Department of Agriculture.

ants do not eat the leaves, but carry them into their underground nests and use them as a medium or soil on which to grow a fungus which they do eat. These ants are real "farmer insects," in that the food they eat is grown by their own efforts. Carbon bisulfide, poured into their nest, may sometimes destroy the colony.

(c) *By Sucking the Juices.* We may distinguish

other groups of insects by the way they get their food from the plant or animal. Instead of having jaws with which they may bite off and chew their food, their mouth parts are shaped into a kind of tube which they use to suck blood or sap, nectar or viscid matter. The squash-bug (Fig. 99) and the chinch-bug get their food by sucking. Plant lice, such as the green bug, and San José scale (Fig. 100) are also sucking insects.

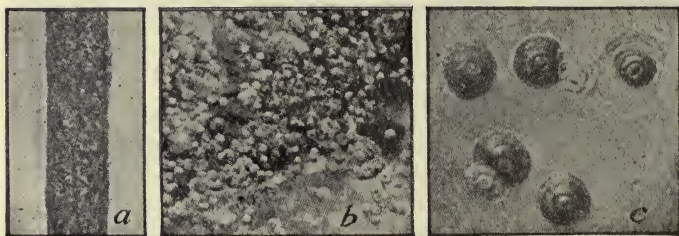


Fig. 100. San José scale on plum. *A*, natural size; *b*, magnified; *c*, greatly magnified.

Insects should not be classed as “biting insects” and “sucking insects” because some species have biting mouth parts at one stage of their life cycle and sucking mouth parts at another. The caterpillars gnaw or bite their food, while the parent moths or butterflies have a sucking tongue. Some kinds with sucking mouth parts are comparatively free, their host and habitat being often unknown. Many kinds, however, have developed fixed parasitic habits. Most of the bloodthirsty pests belong here, such as horse and cattle flies, the mosquitos and the common bed-bug. The sucking insects are usually external feeders. Exceptions are noted in the case of the horse bot and the cattle warble.

230a. Structure of Insects. For this exercise the pupil should secure good specimens of the grasshopper and butterfly, as these

two insects illustrate the difference of mouth parts as seen in insects. Some, as the grasshopper, have biting mouth parts, while others, as squash bugs, etc., have mouth parts suited to suck up the plant juices or nectar. (a) Note the large eyes in the front and side of the head of each insect. These are called compound eyes because they are made up of a great number of simple eyes. (b) Note also the feelers or antennæ, and the mouth parts. The large black jaws of the grasshopper are used for biting, while the long coiled tongue-like organ of the butterfly is used for obtaining food by sucking out the nectar from flowers.

230b. The next region of the body behind the head is called the thorax. In each insect the thorax is composed of three segments. Each segment has a pair of legs attached. All insects have six legs, and are sometimes called Hexapoda on this account. On each insect you will usually find one or two pairs of wings. These wings are attached to the second and third segments of the thorax. Notice that the wings of the butterfly are covered with a "powder." This powder is made up of small scales attached to the wing in rows overlapping each other very much like the shingles of a roof. The wings of the grasshopper are smooth and firm with a large number of small veins.

230c. The next section of the body behind the thorax is called the abdomen, which is made up of a number of segments or rings. By looking along the side of the abdomen of the grasshopper there will be seen a number of small openings or pores. These are the breathing pores and nearly all insects have such breathing pores on the abdomen and thorax. At the tip of the abdomen the segments are changed a little in their form and size. This tip of the abdomen of the female is the egg depositor. The grasshoppers usually bore down into the ground and deposit their eggs, while other insects deposit their eggs in the bark of trees, young fruit, etc.

230d. Collect some of the common insects from the plants in the school-garden, or from the fields, and determine whether they have sucking or biting mouth parts.

231. General Method of Destroying Injurious Insects. The number of injurious insects appearing at any one time is affected by their food supply, weather conditions, and their natural enemies, such as birds, lizards, and other kinds of insects. Wherever it is possible, encour-

agement should be given to these common enemies. Field pests can sometimes be killed by running heavy rollers over the fields, or by plowing or harrowing.

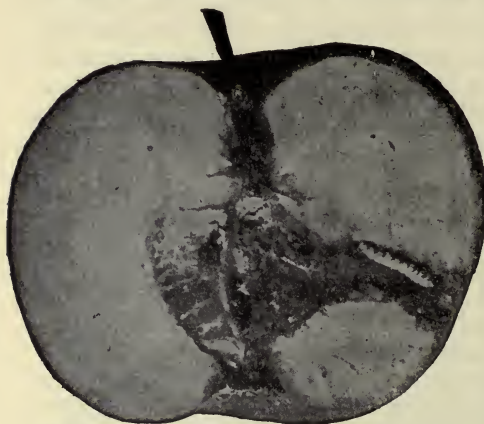


Fig. 101. This apple might have been kept sound by spraying. From Cornell University Junior Naturalist.

The leaf-eating forms can frequently be killed by spraying the leaves with poisons. Others, like the sucking insects, may be killed by spraying directly onto the insect some substance that kills by contact, such as oils, alkali washes, etc. The poison must not be strong enough

to injure the plants. In some cases, the insects may be killed by treating the plants with poisonous fumes or gases, such as tobacco smoke, and the deadly hydrocyanic acid gas, used especially for San José scale. Where plants are sprayed to prevent fungous diseases, the poison for insects may be applied in the same solution at the same time. There are many kinds of special machines for applying fungicides and insecticides. They are fully described in special books and bulletins.

232. Classification of Insecticides. Substances that are used to poison insects are called insecticides. There are many substances used to kill insects. They may be grouped into three classes, according to the manner in which they poison the insect.

(a) *Food, or Internal Poisons*, are substances which poison by being taken into the digestive tract of the insect. This class includes various arsenical compounds, such as Paris green, London purple, lead arsenate. Poisons of this class are used for insects that chew their food, as the leaf-eating forms, unless the use of the poison



Fig. 102. Spraying in the late dormant season.

renders the plants dangerous for food, such as cabbage.

(b) *Contact Poison*. Substances that destroy by attacking the body of the insect, such as washes of caustic alkalies, oils, etc. They are used for sucking insects, i.e., those having beaks, such as the San José scale.

(c) *Fumigation Poisons*. Substances which enter the breathing pores of the insect and cause death by poisoning or suffocation. Smoke, and the deadly hydrocyanic acid gas, Pyrethrum, or "insect powder," and carbon bisulphide, belong to this class.

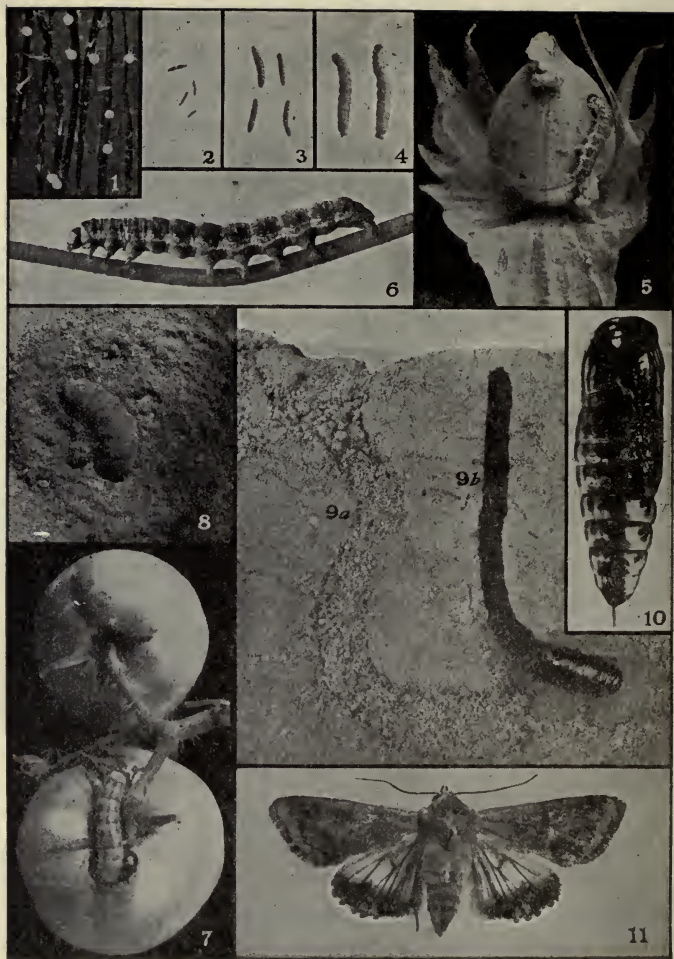


Fig. 103. The cotton-boll worm. After Quaintance and Brues. 1, Eggs on corn silk, twice natural size; 2-4, early larval stages, somewhat enlarged; 5, boll-worm eating into half-grown ball, natural size; 6, mature larva, natural size; 7, boll-worm on green tomato, one-half natural size; 8, full grown larva burrowing into soil for pupation; 9a, showing line of movement of larva into the soil; 9b, pupal chamber with pupa at bottom; 10, mature pupa, slightly magnified; 11, boll-worm moth with wings expanded, natural size.

CHAPTER XXIII

SOME SPECIAL INJURIOUS INSECTS

233. Insects that Attack Cotton. There are several species of insects that injure the cotton plant, such as the cotton army or leaf-worm, cotton boll-worm, the Mexican boll-weevil, and the cotton aphid. The leaf-worm and boll-worm may be destroyed by spraying or dusting with arsenical poisons. (See also Fig. 216.)

234. The Boll-Worm of cotton, destroys the flower-buds or squares, and locks of the bolls. The same insect damages the tips of more than 75 per cent of the ears in the corn fields. The damage to corn ears is probably fully 3 to 5 per cent of the crop. The pupæ hibernate in the ground through the fall and winter and do not mature into moths until late in the spring. These facts



Fig. 104. Mexican Cotton-boll weevil. (Enlarged five times.) Howard, United States Department of Agriculture.

suggest the advisability of early fall plowing to expose the pupa to the severe weather conditions of the winter seasons, predaceous insects and birds. (What other reasons have already been mentioned for early plowing?) Advantage is taken of the habit of the insect of attacking corn and cowpeas in preference to cotton, to protect the latter. "Trap rows" of corn and cowpeas may be planted near the cotton to attract the moths. In this way the damage to the cotton is lessened. Corn is used, also, in pro-

teeting tomatoes from this insect. Corn designed for "trapping" boll-worms should be planted later than the regular crop. Much better results will be secured if the corn is planted late. (Fig. 103.)

235. Chinch Bugs infest corn, wheat, oats, and other



Fig. 105. You can find Chinch bugs in winter quarters in this way if present in threatening numbers. Courtesy Prof. T. J. Headlee.

grass plants. They occur widely distributed and do more damage to field crops than any other insect. They are small, dark colored sucking bugs (see plate), which infest growing grain throughout the warm season. They are usually present in all grain fields during spring and summer months, and do considerable damage that is often not noticed.

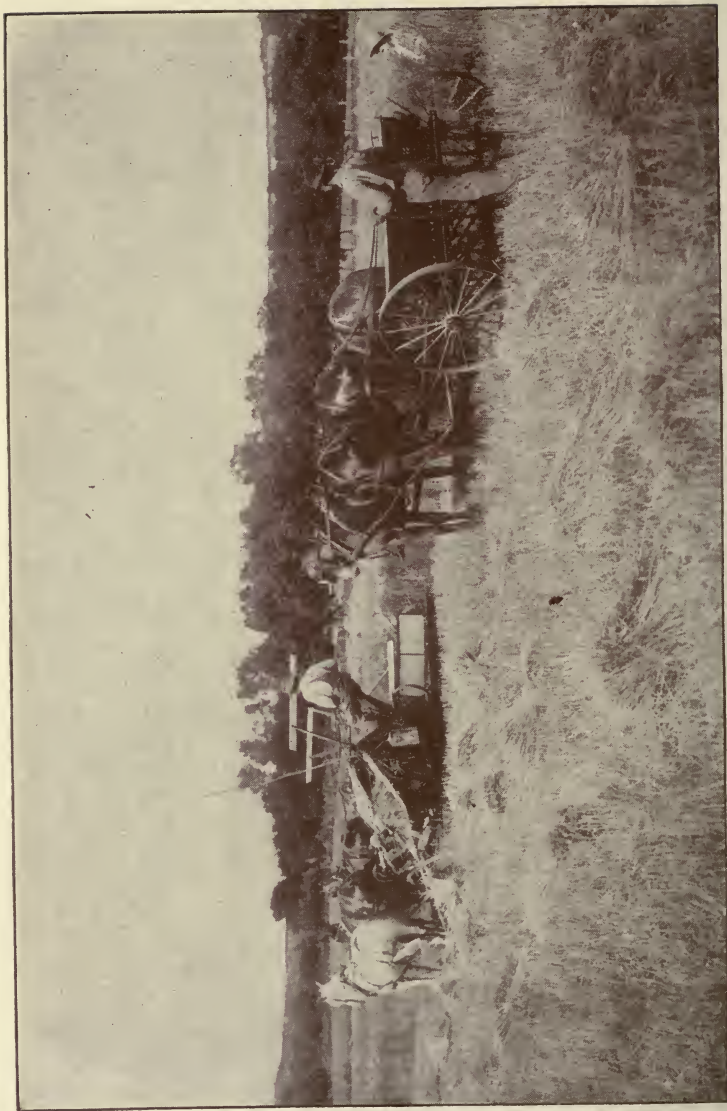
While the chinch bugs have wings, they are inclined to travel by crawling. When a small grain crop is harvested they migrate to near-by corn fields. To protect the corn, the land should be disked at once to destroy the bugs and grass that would feed them. As they migrate to the corn they can be caught in deep dusty furrows and destroyed by dragging a log thru the furrow in the afternoons. They do not migrate



STAGES IN THE DEVELOPMENT OF THE CHINCH BUG

1. Egg, usually deposited on roots, near the crown.
- 2, 3, 4 and 5. Nymphs of different ages.
6. Mature chinch bug

Courtesy Dr. Forbes, University of Illinois.



LOOKING AHEAD FOR BETTER CROPS

Drilling Cowpeas after the harvester to grow a catch crop to enrich the soil for next season's crop.

at night; usually in the afternoons. In wet weather the corn may be protected by a line of tar or crude oil. Chinch bugs pass the winter in tufts of grass (Fig. 105).

236. The Hessian Fly is a native of Europe and is supposed to have been introduced into America by the Hessian soldiers in the Revolutionary War; hence the name. Next to the chinch bug it is the most serious insect pest of the wheat crop. It has been found that the damage can be largely prevented by plowing under the stubble just after harvest and destroying the volunteer wheat in summer. The stubble harbors the pupal stage. [¶ 226.] If turned under



Fig. 106. Hessian fly. *a*, adult, about three times natural size; *b*, pupa or "flaxseed" stage, slightly enlarged; *c*, larvae or maggots, enlarged. After Washburn.

deeply it prevents many of the flies from escaping, and thus reduces the late "summer crop" of flies and maggots.

The adult Hessian fly may be seen in infested fields in late summer or early spring. It is a yellowish brown colored, long-legged, gnat-like insect (Fig. 106). The female lays slender, oval, reddish eggs, lengthwise the grooves on the upper side of the leaves. These eggs, just large enough to be seen with the unaided eye, hatch out tiny reddish larvæ that wriggle down to the stem under the leaf sheath where they feed and grow. The maggots soon lose their reddish color, turn white, form a flaxseed-like brown pupa before cold weather. Some of the pupæ hatch out, producing the "spring crop" of flies. Most of the pupæ, however, remain dormant on the stubble and develop the late "summer brood" of flies, which in turn

produce the destructive maggots. Destroying volunteer wheat starves the summer crop of maggots. Plowing under the stubble destroys the pupæ and prevents the summer crop from developing. Late sowing starves out the early fall crop of maggots. These preventive measures enable wheat farmers to largely overcome the damages caused by Hessian flies.

236a. The Argentine Ant was first noticed in this country at New Orleans, La., in 1891, and has become a serious pest over much territory. The species is a native of Brazil and Argentine and is supposed to have been brought in on coffee ships from Brazilian ports. Recently it has been found in several localities in California. The ants forage both day and night, invading dwellings, swarming over all kinds of food, and even attacking sleeping infants. It bites severely, but does not sting. As an agricultural menace, it destroys buds, blooms, fruit, and fosters plant lice and scale insects (§239). The cotton louse and the sugar cane mealy-bug increase rapidly under the care of these ants. They attack and destroy native ants, and other useful insects. Their nests may be destroyed by using carbon bisulphide, potassium cyanide, or oil. Poisoning is accomplished by using a bait of arsenic in syrup. A jar provided with a perforated top and containing a sponge saturated with the poisoned syrup can be used in the house as safely as out of doors.

236b. San Jose Scale (pronounced *San Hō-sê*) is easily recognized on fruit trees by an incrustation of minute circular bodies with a pimple-like center, as pictured in figure 100. The insect itself lives under the circular scale. Several generations will be pro-

duced in a season. Young scales are possibly carried from orchard to orchard by birds, winds and other agencies, but most usually on nursery stock. Lady bugs (§247) and parasites are important natural enemies, but effective control depends on the use of contact poisons (§232c) when the trees are dormant, preference being given to the lime-sulphur wash. (See appendix B).

237. Tent Caterpillars are often found in fruit trees. They are easily discovered in the spring by their large webs supported on the branches. Small bunches of eggs, like those shown in Fig. 108c, may be found much earlier. These eggs are laid late in the summer and covered by a sticky substance to protect them from the winter rains. They hatch out usually just about the time the buds open and the caterpillars feed on the young buds and leaves. The caterpillars soon spin a delicate cloth-like web or tent, to which they retire at night, and in bad weather. These caterpillars are

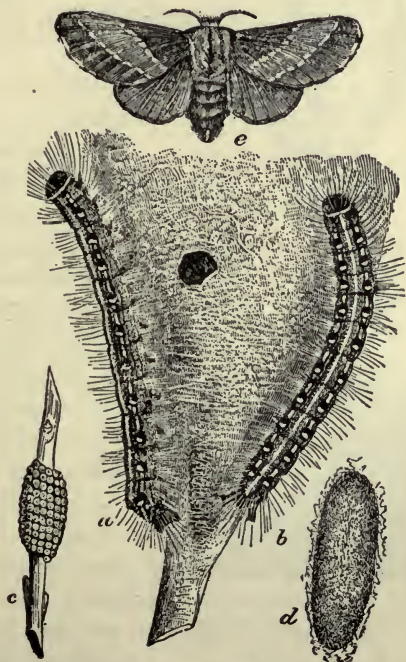


Fig. 108. The tent-caterpillar. *a* and *b*, larvæ; *c*, egg-cluster; *d*, cocoon; *e*, full-grown. After Riley.

well marked with dots and lines along the bodies, that are characteristic for each species. After a time they leave the tree and each individual spins a paper-like case, called a "cocoon," in some sheltered place. The adult moth emerges from the cocoon in a few weeks, and lays the eggs as mentioned above. These changes may be observed by bringing the almost mature caterpillars into wire-screened cages. These caterpillars are attacked by many insect parasites, snakes, frogs, and particularly by birds. The orchard should be inspected in the early spring for webs.

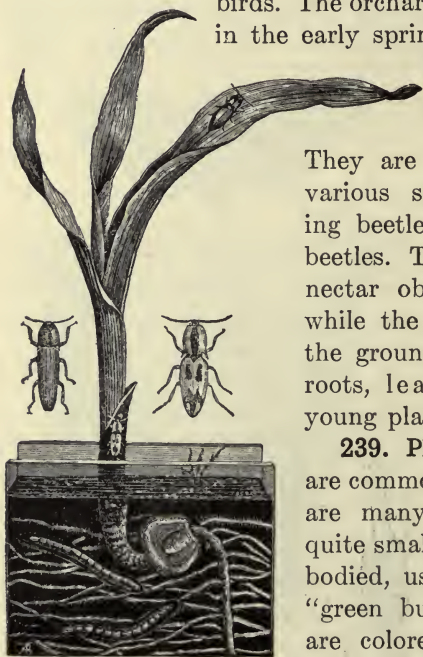


Fig. 109. A corn-plant growing in a root-cage infested by wire-worms and click-beetles. After Comstock.

238. "Wire-worms" are very common in fields.

They are the larval stage of various species of night-flying beetles, such as the click-beetles. The adult lives on the nectar obtained from flowers while the larval stage lives in the ground and thrives on the roots, leaves, and stems of young plants.

239. Plant-lice, or Aphids, are common everywhere. There are many kinds, and all are quite small. Plant-lice are soft-bodied, usually green, like the "green bug," but some forms are colored red or black or other color. Most of them are wingless, though some of them will have two pairs of transpar-

ent wings. They almost always occur in colonies, frequently of immense numbers. They feed upon the leaves, buds, tender stems, and even the roots in some sorts of plants. They do much damage by sucking the plant juices. Some species secrete a substance known as "honey dew," which is sought after by ants. The ants care for the aphids and protect them from the depredations of predaceous insects. The scale insects are somewhat allied to the plant-lice. The San José scale is the most

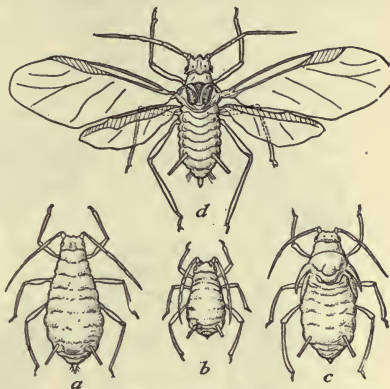


Fig. 110. The spring-grain aphid. *a*, wingless female; *b*, larva; *c*, pupa; *d*, winged migrant. After Webster, United States Department of Agriculture.

serious representative of the many scale insects. (Fig. 100.)

239a. Colonies of plant-lice may be found frequently on roadside weeds, sometimes under the folded edges of leaves tended by ants. Such a colony should be closely observed. Small tubes may usually be seen on the abdomen of the lice. The ants have a way of stroking the lice to make them give off the honey dew. This action is often fancifully called "ants milking their cows."

240. Insects Injurious to Stored Grain. The insects that damage stored grain are the larvæ of moths and beetles, and several species of weevils remotely akin to the plum-gouger and cotton boll-weevil. Corn, wheat, peas, and many other seeds are often damaged by these insects while stored. Some species are very destructive. The "grain-weevil" is the most destructive, particularly to corn, peas, barley, kafir corn, etc. The two most common species of weevil are shown in Fig. 111. The

the rice-weevil is common, and has a dull brown color. The eggs are laid in the corn, often before it is gathered. During warm weather it requires about six weeks to mature a weevil from the egg, while, in cold weather,

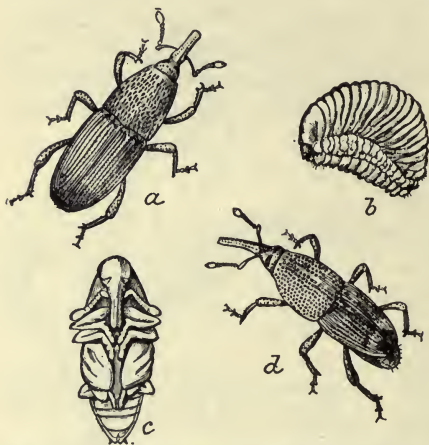


Fig. 111. Granary weevil. *a*, adult; *b*, larva; *c*, pupa; *d*, rice weevil. All enlarged. After Chittenden.

they multiply very slowly. The egg-laying continues over a considerable period and, as it requires such a short while to mature a new brood, it is no wonder that they are found in such numbers in grain stored for any considerable time. It is estimated that, in the course of a season, they mature six or

more generations, amounting to 500 or more individuals from a single pair.

241. The Grain Moths do more damage to the stored grain than the weevils. The most common species is the Angoumois grain moth, so named from the province of Angoumois, France. It attacks grain in the field as well as in the bin. The adult somewhat resembles the common clothes moth. It is light grayish brown and about a half-inch across when the wings are expanded. The eggs are deposited in clusters of twenty to thirty and require only about four to seven, or more, days to hatch the caterpillars. The latter bore into the

grain, and, after feeding on the starchy matter for about three weeks, form a thin silken cocoon, from which the adult moth emerges in a few days. About thirty-five days are used in passing from egg to adult. Four to, possibly, eight broods mature during the year. When grain is stored in bulk, only the surface layers are infested. Both the weevils and moths are subject to attacks by parasites.

242. Preventing Injury to Stored Grain. To reduce the injury to stored grain, use is made of repellants like naphthalene (so-called "moth balls"), salt, air-slaked lime, and other substances which, while not poisonous, drive the insect out. A temperature of 125° Fahr. is sufficient to kill weevils, though more than 150° Fahr. may be endured by dry grain without loss of germinating power. Treating the grains to the vapors of bisulfide of carbon in tight bins is by far the most satisfactory means of protecting stored grain. In destroying the insects, use one pound to one hundred bushels of grain.



Fig. 112. Angoumois grain moth.

CHAPTER XXIV

USEFUL INSECTS

243. Useful Insects. Some insects are useful because they supply food, as the honey-bee. Others supply materials for clothing, as the silkworm. Still others, as we have seen, cause flowers to set fruit by carrying pollen from flower to flower. (See ¶ 167.) There are many species which are especially useful in man's battle with the forces of nature, because they prey upon the injurious insects.

244. Wasps. There are many kinds of wasps. The common "red wasps" and "yellow jackets," with their paper nests made out of the fragments of plants, are well known. The mud-dauber is another common wasp. There are many species of wasps that do not live in colonies like the ones just mentioned, but live singly. and are, hence, called "solitary wasps." The wasps are somewhat related to the domestic bees, and bumblebees. But instead of storing nectar and pollen for food, as the bees do, they fill the cells of their nest with the younger stages of other insects as food for the young wasps. The adults prefer nectar and pollen for themselves, however. The mud-dauber fills the mud-cells with the bodies of young spiders, flies, etc., and before sealing up the hole, deposits an egg. The food for the larva is there ready for it when it is hatched. Wasps are said to catch the biting flies that worry stock; and, especially, the larvæ of the boll-worm. Wasps' nests should not be destroyed except, possibly, in orchards.

245. Ichneumon Flies, of which there are many kinds, are somewhat related to the bees and wasps. The adult often feeds on nectar. The usefulness of this class of insects is due to the fact that the young are parasites. They do not secure their prey by force. Instead of catching the insects and carrying them to the young larvæ, their eggs are deposited in or on the bodies of their victims, and there grow into grubs. The grubs mature in or on the body of the hosts. The eggs of the

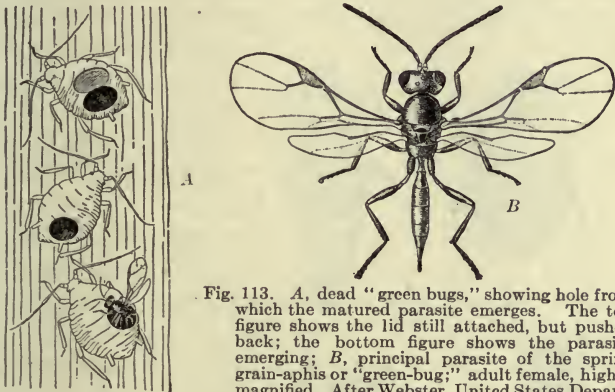


Fig. 113. A, dead "green bugs," showing hole from which the matured parasite emerges. The top figure shows the lid still attached, but pushed back; the bottom figure shows the parasite emerging; B, principal parasite of the spring grain-aphis or "green-bug;" adult female, highly magnified. After Webster, United States Department of Agriculture.

parasite are most often deposited in caterpillars, though sometimes in the chrysalis, pupa, or on the adult stage, or even in the eggs of their hosts. Entomologists formerly thought that each kind or species of parasitic insect secured its food from just one or two kinds of hosts, somewhat similar to that noticed in the parasitic fungi previously mentioned (§ 217). Recent investigations have shown that there is much less restriction in feeding habits among parasitic insects than was formerly

thought. One species (Fig. 113) of ichneumon fly is important because it attacks the green bug, usually in sufficient numbers to prevent serious injury. This parasite thrives only during warm weather, however, while the green bugs may endure much cold weather. Below central Texas, the parasitic flies are active at all seasons and that section has never been seriously damaged by the green bug. In other parts, the entire grain crops have been almost destroyed several times because the cool weather retarded the multiplication of the parasites.

Ichneumon flies are parasitized by other ichneumon

flies, and these in turn by others, reminding one of the old adage that "Large fleas have smaller fleas to bite 'em."

246. Ants. Many species of ants live on the eggs and larvæ of other insects. The "fire ants" in particular are very useful in cotton fields because they destroy many grubs of boll-weevils in fallen buds. The common red stinging ant lives on weed seeds and wild grain, and sometimes attacks other insects.

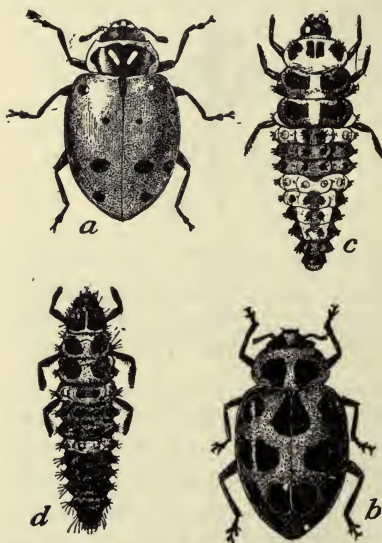


Fig. 114. Two common species of lady bugs. *a*, *hippodamia*; *b*, *megilla*; *c* and *d*, larva stages. After Chittenden, United States Department of Agriculture.

Some forms of ants, particularly some tropical species, are serious pests.

247. Lady Bugs are another class of insect-eating insects. They feed on eggs of the Colorado potato bugs, and on plant-lice. The larger forms are easily recognized by their red and black-spotted color. Two important kinds of lady bugs are pictured in Fig. 114. One species, *Megilla maculata* (Fig. 114), is especially active in feeding on the green bug on grains, while another, *Hippodamia convergens*, is more active on the plant-lice on cotton and melons. The latter will lay about fifteen eggs per day, and often a total of 500 eggs. These are deposited on leaves in clusters of from a few to fifty in a place. A lady bug will eat about fifty aphids per day. We recognize these insects as a benefit to mankind in various ways.

248. Parasitic Insects are possibly the most important class of beneficial insects. Without them, the locusts or grasshoppers, the caterpillars of butterflies and moths, and many other kinds, would destroy all the plants. Every farm in extreme southern regions should have a "lady bug patch." They require plenty of insect food for rapid multiplication and this should be provided by growing some crop that harbors insects through the winter. Some winter-growing plant, like rape, which has a winter insect parasite, the cabbage aphid. The lady bugs, thus having food through the winter, grow and multiply until spring when food naturally becomes abundant.

CHAPTER XXV

WILD BIRDS AND OTHER INSECT-EATING ANIMALS

249. Most Birds Benefit the Farmer, because their food consists very largely of harmful insects, weed seeds, mice, etc. Some birds eat the grain or do much damage to the fruit, but without the birds, the insects would be far more destructive. In 1753, Benjamin Franklin wrote to a friend:—"In New England they once thought blackbirds useless, and mischievous to the corn. They made efforts to destroy them. The consequence was, the blackbirds diminished, but a kind of worm which devoured their grass, and which the blackbirds used to feed upon, increased prodigiously; then, finding their loss in grass greater than their gain in corn, they wished again for the blackbirds."

250. Birds Like Insect Food Best. Every one has noticed how the field-larks, and other birds, fly into the newly plowed furrow. They are not looking for freshly planted seeds as some suppose, but for worms and insects which the plow uncovers. They prefer insects, but will eat weed or grain seeds if insects are scarce. In summer the field-lark (or "meadow-lark," as he is most often called in the North) eats insects

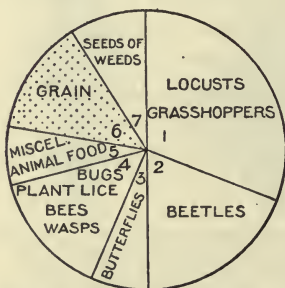


Fig. 115. Food of the meadow-lark by months.

almost entirely, but in winter when he cannot find insects, he has to eat weed seeds, and waste grain. (See Fig. 115 and table of food by months.) The young of all kind of birds, including those of the vegetable-feeding adults, feed largely on insects. (See Fig. 116.)

FOOD FOR THE YEAR.

Months	Stomachs Examined	Animal Food Per cent	Grain Per cent	Weed Seeds Per cent	Total Per cent
January	13	24.36	75.28	.36	100
February	1	.00	25.00	75.00	100
March	12	73.14	17.00	9.86	100
April	28	77.51	15.10	7.39	100
May	8	97.99	1.88	.13	100
June	20	95.79	2.10	2.11	100
July	18	97.32	.00	2.68	100
August	28	99.35	.00	.65	100
September	29	99.20	.40	.40	100
October	40	94.39	.61	5.00	100
November	22	77.08	6.50	16.42	100
December	19	39.22	32.70	28.08	100
Total for year	238	72.95	14.71	12.34	100

251. Beneficial Birds Should not be Killed for food, neither for sport, nor for decorations for hats. Every

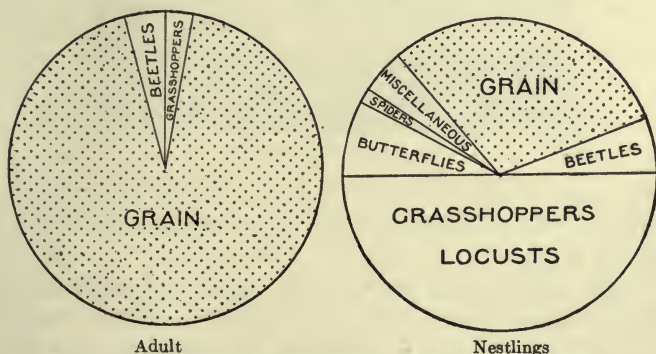


Fig. 116. Diagram showing proportions of food of English sparrow young and adult.

time one feels tempted to kill birds, he should not only think of the good they do by destroying insects and weed seeds, but possibly not far off there is a group of tender nestlings waiting for mama or papa bird to come home with a morsel of food, to check the pangs of hunger. When women decorate their hats with aigrettes, they encourage selfish persons to kill harmless birds. It is against the laws of many states to kill the useful birds. No one should want to destroy them. Birds should be protected at all seasons. Define "game birds" and "Non-game birds," as used in the laws of your state.

252. English Sparrows (Fig. 117) live almost exclusively on the farmers' crops, besides destroying the

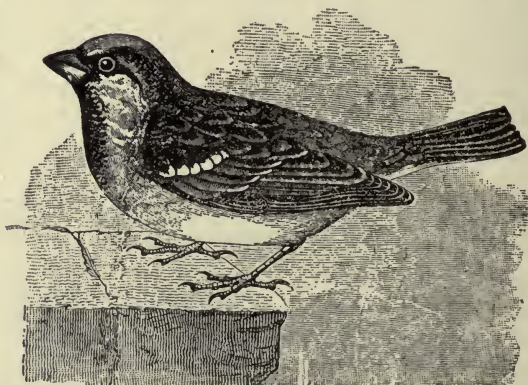


Fig. 117. English sparrow.

eggs and nests of other birds. They should be destroyed. The native species of sparrows are insect-eating birds.

253. Migration of Birds. Some birds live all the time in the same locality, like the partridge, Texas road-runner, and downy woodpecker, the sparrow, and the

cardinal, while other kinds, as the robin, bluejay, etc., spend one season in one part of the world, and the others elsewhere.

Everybody knows that the wild geese "fly over" in the fall, going south to the warm salt waters, and back again in the spring on their way to the breeding-grounds in Canada. Likewise, the field-lark spends the summer in the North, and in the fall and winter he makes his home in the South. (Fig. 118.)

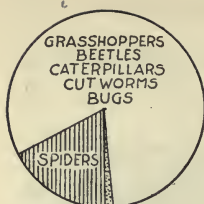


Fig. 118. Meadow lark or field lark.

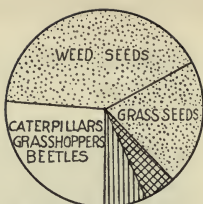
253a. Make a list of the kinds of birds, found in the county.

How many kinds are permanent residents, and how many visit for only a part of the year?

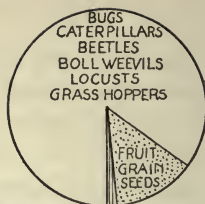
254. The Feeding Habits of Birds. The farmer is interested in the birds because they eat the insects that destroy his crops. The illustrations, Figs. 119 and 120, show how much of each kind of food some common birds eat. Some birds, like the swallows and scissor-tailed flycatcher, live on insects almost entirely. Others, like the dove, eat nearly all weed seeds and grain, but most birds eat some of both. It will be interesting to



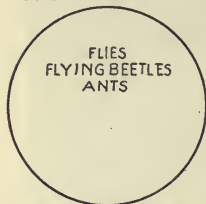
1 House Wren



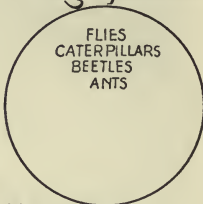
2 Song Sparrow



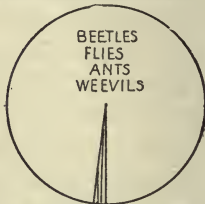
3 Orchard Oriole



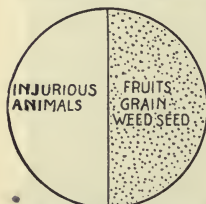
4 Bank Swallow



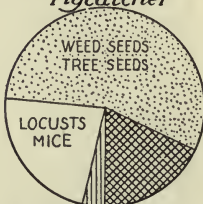
5 Scissor-tail Flycatcher



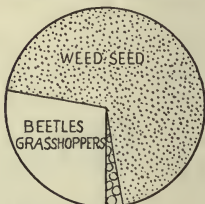
6 Barn Swallow



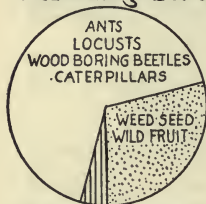
7 Mocking-bird



8 Blue Jay



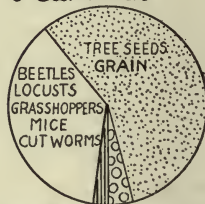
9 Cardinal



10 Red Headed Woodpecker



11 Red Winged Blackbird



12 American Crow

Beneficial Animals



Injurious Animals



Fruits



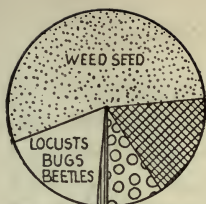
Grain



Wild Seed



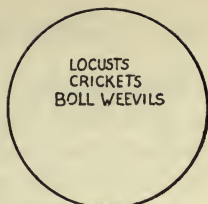
Fig. 119. Diagram illustrating the proportions of the food of various beneficial and destructive birds.



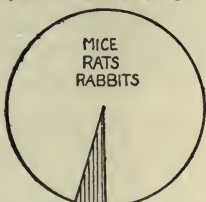
13 Bob White



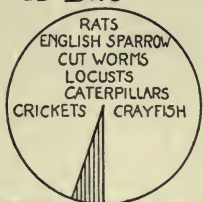
14 Dove



15 Killdeer



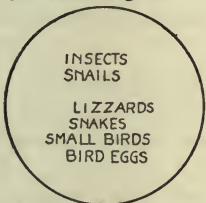
16 Barn Owl



17 Screech Owl



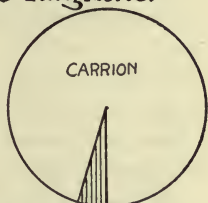
18 Kingfisher



19 Road-Runner



20 Hummingbird



21 Buzzard



22 Toad



23 Horned Lizard



24 Chicken Snake

Beneficial Animals

Injurious Animals

Fruits

Grain

Wild Seeds

Fig. 120. Diagram illustrating the proportions of the food of various beneficial and destructive birds.

watch the many kinds of birds in your neighborhood, and see how they catch their food. The scissor-tails capture the insects that fly during the day. At night the whippoorwills and night-hawks begin to fly, and catch the insects that the day-flying birds miss. Some kinds of birds, like the wren and vireos, go carefully from leaf to leaf, looking for the small, half-hidden insects on the under sides. Still, again, the busy woodpecker goes over the bark looking for insect eggs and larvæ, or boring for ants and wood-worms. Other birds, like the larks and sparrows, scan the ground for creeping insects, while still others, with long legs and bills, go to the bottom of the pool for the little swimmers that are seemingly safe from molestation.

254a. If a bird eats on an average one hundred insects a day, and there are three birds to every acre of land, how many insects will they eat in a year? How many insects would they take from the largest orchard in the neighborhood?

254b. A quail was found to have 10,000 weed and grass seeds in the craw when killed. If each quail in a covey of fifteen should destroy this many weed seeds daily for a year, how many weeds would be destroyed?

255. Change of Feeding Habits in Migration. Some birds that spend a part of a season in one part of the country, and the other in a distant section, change their feeding habits. A good illustration is the bobolink, or rice bird. It breeds in the North, and feeds largely on insects, and but slightly on grain. In the South it is called "rice bird" because it prefers the rice field, where 50 to 80 per cent of its food is rice.

256. Bird-houses. Instead of shooting at birds, and throwing stones to scare them, we should encourage the useful birds to build their nests around the barns and in the orchards. Many persons build houses to

attract martins and sparrows. A simple house may be made with old tin cans, as shown in Fig. 121, using a board for a roof, and allowing part of the top of the can

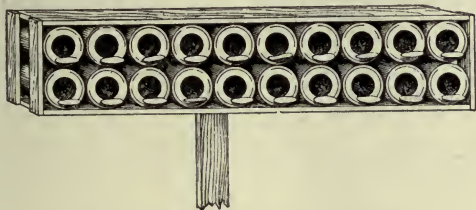


Fig. 121. A good way to use tin cans.

to remain, to make a lighting place. A good house for martins is shown in Fig. 122.

257. Other Animals that Destroy Insects. “Horned frogs” (though they are really horned lizards) and common toads live on insects, as, also, do most snakes. Even the old chicken snakes make way with many times more rats and mice than they do with young chickens.

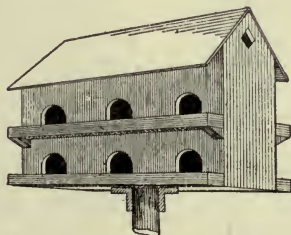


Fig. 122. A simple martin house.

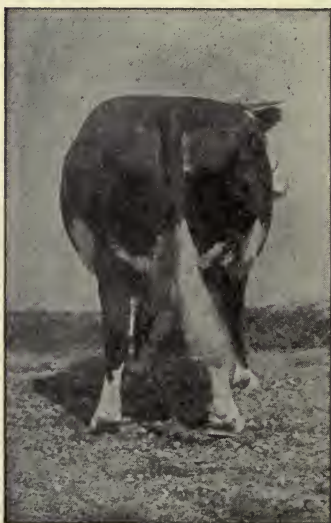


Fig. 123. Side, front and rear view of Hereford cow, "Lady Briton 16."

PART II

CHAPTER XXVI

ANIMAL HUSBANDRY

258. Utilizing Farm Crops. The farmer grows grass, alfalfa, grains, cotton, fruits and other crops which he desires to convert into money. There are two ways of marketing the surplus feeds grown on the farm: (1) The crops may be sold to other persons to be fed to stock, or (2) they may be fed to animals on the farm where they are produced and worked up into a variety of products of less weight and bulk, as beef, pork, poultry, eggs, milk, horses, mules, cows, etc. These finished products may often be marketed for much more than could be secured for the feed alone. And, in addition, there will be retained on the farm much of the fertility, in the feeds, for the benefit of succeeding crops.

258½. Good Live Stock and Good Pastures should be a feature of most farms. It is a singular fact that in states having the largest number of live stock on the farms that the average earnings of such farms are usually greater than in states where the care of live stock is not an important part of the farmer's work.

259. The Farm is a Factory where the plant and animal products are made from the crude substances of the air and soil. It is just as necessary to keep the soil able to sustain large yields as to keep the machinery in the mills in good working order. The wealth-pro-

ducing power of the farm lies in the productiveness of the soils. It costs something every year to restore to the soil the power to make a large yield of wheat (see ¶111), but it costs more to grow wheat on land that averages only half-crops during the life of a farmer.

260. The Cost of Manufacture and the value of the feeds should be counted against the value of the products. The value of a product is determined by its kind, the supply offered at a given time, and the demand.

261. Animal Husbandry is the natural companion of crop farming. When the products of the fields and meadows are removed from the farm each year, there is a continual loss of fertility, which leads to certain poverty of the farm and farmer. When these are fed to the stock on the farm much of the fertility in the crops may be returned to the land.

262. Stock Farming varies and distributes the farmer's labor. It gives him opportunity to work every day in the year by which he may earn something for his family. An all-grain crop or hay crop, or cotton crop, etc., overtakes the farm labor in one season and leaves it in comparative idleness the next. Stock farming encourages system in rotation of crops, and thus tends to maintain the land in a high state of productiveness.

263. In Selecting Animals for the Farm, the farmer should use just as good judgment as the manufacturer does in buying machinery, for the stock is the machinery that makes the crude products of the farm into salable products. The machines used in manufacturing have been greatly improved to cheapen production in special lines. What shall be the character of the machines which the farmer uses to convert his feeds into finished products? Shall it be the latest improved,—by years of

DAILY MILK AND FEED RECORD FOR MONTH

Owner of Herd, J. G. Smith; Post Office, Birmingham

NAME:	Lilly			Spot			Daisy			Cherry			Brindle		
BREED:	Jersey			Holstein			Grade Jersey			Grade Durham			Native Cross		
Date of feed record, ¹	5	15	25	5	15	25	5	15	25	5	15	25	5	15	25
Cow No. Hay:	10	10	10	12	12	12	8	10	8	11	12	10	10	10	10
Silage or sodding crop:	25	25	25	35	35	35	30	30	30	35	35	35	35	35	35
Grain:															
Cotton Seed meal	2½	2½	2½	3	3	3	3	3	3	3	3	3	3	3	3
DATE.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.
1	13½	11	16	13	10	11	10	8			3	3			
2	12	11	15	13	10	9	9	8			4	3			
3	14	12	16	14	11	10	9	9			4	2			
4	14	13	17	15	11	11	10	10			4	3			
5	14½	14	17	16	12	10	10	10			3	3			
6	14	14	17	15	12	11	11	10			3	2			
7	15	14	17	16	12	12	11	10			3	3			
8	15	12	17	15	12	11	10	10			3	2			
Cold Rain 9	14	11	15	13	12	10	10	9			2	2			
Cold Weather 10	14	12	15	13	12	10	10	9			2	2			
" " 11	14	13	15	14	12	11	8	8			2	2			
12	15	14	17	15	13	11	9	8			3	2			

30	15	13	15	15	11	10	10	9			3	2			
31	15	15	16	15	10	9	10	8			3	2			
TOTAL,	441	401	576	461	350	324	305	274			91	75			
Total for month,	842		967		674		579				166				
Butterfat, per cent,	6%		3½%		5%		4%				3.8				
Butterfat, lbs.,	50.52		33.84		33.70		23.16				6.3				
Butter or cream, lbs.,															
Price per gal. 25¢	25¢		25¢		25¢		25¢				25¢				
Value,	\$12.63		\$8.46		\$8.42½		\$5.79				\$1.57				
Value skim milk,	1.79		2.16		1.48		1.30				.37				
Total value,	14.42		10.62		9.90½		7.09				1.94				
Cost,	2.69		4.58		3.72		4.32				4.42				
Profit,	\$11.73		\$6.04		\$6.18½		\$2.77				\$-2.48				

D. D. 165-12-16-27-5-100.

¹ Cost of pasture per head.

Fig. 124. Record of five cows for one month. Is the profit above cost of feed sufficient to pay for care? Records furnished by Prof. C. O. Moser.

breeding and selecting, to secure a breed that will give a larger or more valuable return in meat, butter, eggs, wool, etc., for each pound of feed supplied?

264. Many Animals Are Unsited for the purpose for which they are kept. The Illinois Agricultural Experiment Station made individual records for a full year of the butter produced by 554 cows in Illinois dairies. The average for the 139 poorest was 133.5 pounds of butter-fat and for the 139 best, 301 pounds, or an average difference of 167.5 pounds butter-fat per year. At 25 cents per pound this is \$41.87 per cow.

264a. Figure the gross and net returns per year to the dairyman for labor and interest on the investment for each of the above groups of cows. Allow \$30 per year for the cost of feed for each cow, and 25 cents per pound for butter-fat. The cows were valued at \$50 each. Were they all worth this much?

265. Records of Individual Performance should be made of cows, hens, etc., to determine the cost of keeping and the returns of the farmer. By this means the profitable animals may be recognized, as also the unprofitable ones. The latter should be discarded. The farmer may, by attention to these matters, learn that some animals are being fed at a loss. (Study Fig. 124.)

265a. Milk and Butter Records. Secure records of the amount of milk, and amount of butter, from cows in the neighborhood for a single week. Calculate the value of the product at current prices. Count the amount and cost of the feed consumed. Determine the returns for labor, etc. (See Fig. 124 and ¶352.)

265b. Growth of Pigs. Weigh a weaned pig once a week for four weeks, and calculate the daily gain in weight. Allow for cost of feed and calculate the cost per pound gain. Market prices may be secured from the daily papers.

265c. Record of Loretta D. (see Fig. 131), the champion "best cow of any breed" for economical butter-production in the dairy test at the St. Louis Exposition in a 120-day test was, average daily

flow of milk 48.35 pounds, containing 2.33 pounds of actual butter-fat (equal to 2.75 pounds of standard quality butter). The cost of her feed was twenty-five cents per day. Calculate the value of the milk and butter for ten months.

265d. Record of Colantha 4th's Johanna (see Fig. 125), in a year test completed December 24, 1907, was 27,432 pounds milk, yielding 998 pounds of butter-fat. This is the world's record, both for milk and butter, for any cow of any breed. What would be the value of her milk and butter at current prices?

BREEDS OF LIVE-STOCK

266. What Constitutes a Breed? Breed, as applied to live-stock, corresponds to *variety* in cultivated plants.



Fig. 125. A famous Holstein, Colantha 4th's Johanna

RECORD OF COLANTHA 4TH'S JOHANNA.

Days	Time	Milk	Butter-fat		Estimated butter
		Lbs.	Per cent	Total	
1	Feb. 6, 1907	100.8	3.96	3.99	4.65
7	Feb. 6 to 12.....	651.7	4.37	28.17	32.86
30	Jan. 21 to Feb. 20	2,873.6	3.86	110.83	129.30
60	Dec. 27 to Feb. 25....	5,326.7	3.91	208.39	243.12
365	Dec. 24, '06 to Dec., '07	27,432.5	....	998.25	1,165.00

The various breeds of poultry, cattle, horses, sheep, etc., descended from a common stock. The differences which we recognize in the breeds are the result of continued selections.

267. Origin of Breeds. Man long ago recognized differences in the ability of individual animals to convert their food into milk, wool, feathers, eggs, etc. Therefore we select animals, not so much for their ability to endure hardships, but for their power to produce something in response to care. Continued selection has produced breeds of animals having certain characters strongly developed. They are called "special-purpose breeds."

Many persons are content to perpetuate animals having merely the form and color markings of the breed or strain. Intelligent breeders, however, while trying to preserve the obvious features in color and bodily form that belong to the breed or strain in which they may be interested, also give close attention to habits and *records of performance*. Of two animals receiving the same feed and care, one may gain more than another. Or, again, of two animals having the same weight, as dairy cows, one may consume more feed, with a corresponding increase in products. There are many cows that may consume less feed than Loretta D, and still require more feed to produce a pound of milk or butter.

CHAPTER XXVII

TYPES AND BREEDS OF CATTLE

268. The Beef Types are distinguished by their ability to lay on large amounts of flesh. Their bodies have a rounded form, with strong back and well-sprung ribs. They have full quarters, straight bottom and top



Fig. 126. Outlines of shape of beef cows compared with parallelograms.

lines (see Fig. 127), and a tendency to develop flesh at an early age. Careful breeders prefer the animal that locates a large amount of its flesh where it is worth most, i. e., in regions supplying the valuable cuts of steak. (See Fig. 128.) Animals having these qualities so fixed by repeated selections that they regularly appear in the offspring, belong to the beef-breeds.

269. The Shorthorn, like the Herefords, is an old English breed. The shorthorns adhere closely to the

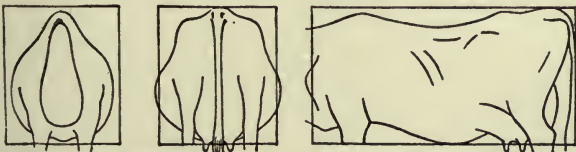


Fig. 127. Outlines of shape of dairy cows compared with parallelograms.

beef type, but many strains are good milkers, and are classed as "general purpose" animals. They are of very

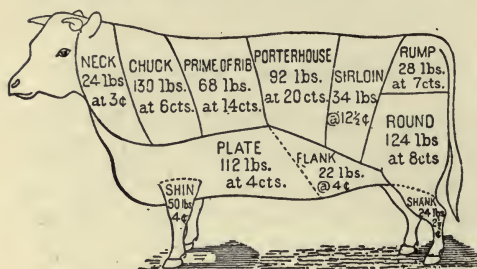


Fig. 128. Chicago retail dealers' method of cutting beef,

large size, the cows often ranging from 1,400 to 2,000 pounds. The horn is short, the hind-quarters are broad and well filled. A considerable range of color is allowed

in the shorthorns,—from light to dark red, or roan, the latter formed by a mixture of red and white hairs. The Polled Durhams are an offshoot of the Shorthorns. (Fig. 129.) The Shorthorn is one of the most popular of beef breeds. During the course of its development three



Fig. 129. A prize-winning Polled Durham. Ruby of Buttonwood.

types have come to be recognized—the Bates, Booth, and Crookshanks, or Scotch Shorthorns. The former two are English in origin and differ from each other in the following characters: The Bates cattle have been bred for beauty and symmetry, style and milking qualities, while in the Booth strain constitution, wide thick-fleshed backs and length of quarters have been empha-



Fig. 130. A typical Aberdeen Angus.

sized. The Crookshanks, or Scotch strain, are low, have blocky forms with large scale, heavy coats of hair, and mature quite early.

270. The Herefords take their name from the county of Hereford, England, where the breed originated. They are typically a beef breed, hardy, early maturing, and well suited to range conditions. In milk-production they are very poor. The red body color and white face are well-fixed marks for the breed. (See Fig. 123.)

271. Aberdeen-Angus derive their name from two counties of northern Scotland. They are polled or hornless and noted for their fine beef qualities. Their place as a range breed is not yet established, though as feeders they have many friends. The body is very compact and more cylindrical than that of either Herefords or Shorthorns. The legs are short and heavy. Color is nearly always black. They are classed as medium milkers among beef breeds. (Fig. 130.)

272. Dairy Types are noted for their ability to produce large quantities of milk and butter, instead of flesh. They are noticeable for their long, deep couplings, triple wedge-shaped outlines, due to their clean-cut shoulders and broad, deep hind-quarters, clean-cut limbs, slender necks and sharp withers. They also have a full barrel, indicating strong constitution, and well-developed digestive systems, well-developed udders, and a capacity to yield a quantity of milk and butter on moderate feed. The important dairy breeds are the Jerseys, Guernseys, Holstein-Friesian, Ayrshires and Dutch Belted.

273. The Jerseys and the Guernseys are natives of the islands of these names in the English Channel. The typical color for the Jersey breed is described as fawn, gray, and silvery fawn. White marks are not infrequent. The tongues and switch of the tail are typically black in pure-bred Jerseys. In conformation, the Jersey adheres strictly to the dairy-type characteristics. The weight of the cows averages between 650 and 850 pounds. Their milk is noted for its richness in butter-fat, a fair average being close to 4.5 per cent fat in the milk. As a beef producer, the Jersey is very poor. A number of famous Jerseys have records ranging from 700 to 1,000 pounds of butter in a single year. •



Fig. 131. Loretta D. A Jersey cow with a good form and a good record.

OFFICIAL MILK, FAT AND BUTTER YIELDS OF LORETTA D.

Days	From	Milk		Fat		Estim'd butter*	
		Total	Daily average	Total	Daily average	Total	Daily average
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
120	June 16-Oct. 13. ..	5,802.7	48.35	280.16	2.33	330.03	2.75
30	Aug. 28-Sept. 26 ..	1,442.8	48.09	73.68	2.45	86.94	2.90
7	Sept. 17-Sept. 23 ..	335.2	47.90	17.67	2.52	20.85	2.98
1	Aug. 13.....	50.65	....	3.13	....	3.71	....

274. The Holstein-Friesian, or simply Friesian, as they are called in their native country, Holland; is a splendid dairy type with large frame. The color is black

* In calculating the amount of commercial butter, add one-sixth to the net butter-fat, to allow for the moisture in the butter.

POINTS AND MEASUREMENTS TO BE OBSERVED IN JUDGING CATTLE

- | | |
|--|---|
| 1. Mouth. | 33. Hooks or hips. |
| 2. Lips. | 34. Crops, depression behind shoulder. |
| 3. Nostrils. | 35. Fore-ribs. |
| 4. Muzzle. | 36. Girth at flank. |
| 5. Face, from muzzle to poll. | 37. Chest cavity. |
| 6. Forehead, from eyes to poll. | 38. Chine, between withers and loin. |
| 7. Eye. | 39. False or floating ribs. |
| 8. Cheek, side of head below | 40. Belly. |
| 9. Jaw. [eye. | 41. Milk-veins, branched and tortuous ducts running forward beneath the barrel. |
| 10. Throat. | 42. Orifices through which the milk veins enter the abdominal walls. |
| 11. Brains. | 43. Midribs. |
| 12. Ear. | 44. Abdominal depth, indicating digestion and constitution. |
| 13. Poll, top of head. | 45. Tail head. |
| 14. Horns. | 46. Pin bones. |
| 15. Neck. | 47. Escutcheon, covered with fine hairs. |
| 16. Neck, lateral view. | 48. Buttocks. |
| 17. Breast or bosom, front of chest. | 49. Twist where hair turns on thigh. |
| 18. Fore flank, rear of arm. | 50. Gaskin or lower thigh. |
| 19. Dewlap, loose skin, underneath the throat. | 51. Brush. |
| 20. Brisket, point of chest. | 52. Thigh. |
| 21. Withers, top of shoulders. | 53. Stifle. |
| 22. Shoulder point. | 54. Flank. |
| 23. Neck or collar depression in | 55. Udder. |
| 24. Elbow. [front. | 56. Teats. |
| 25. Arm. | 57. Hock. |
| 26. Fore arm, portion of leg between elbow and knee. | 58. Navel or umbilicus. |
| 27. Knee. | 59. Face. |
| 28. Cannon or shank-bone, between knee and ankle in fore- or hind-leg. | 60. Pelvic arch or sacrum, between the loin and crupper. |
| 29. Hoof. | |
| 30. Spinal column, backbone. | |
| 31. Barrel or coupling, middle-piece. | |
| 32. Loin, muscle covering the short ribs. | |

MEASUREMENTS.

- | | |
|---|---------------------------------|
| A. Width of forehead. | E. Height at withers and hooks. |
| B. Length of neck. | F. Girth at chest and navel. |
| C. Width of breast. | G. Length of barrel depression. |
| D. Length from pin bones to shoulder point. | H. Width of hooks. |
| | K. Length of hind-quarters. |

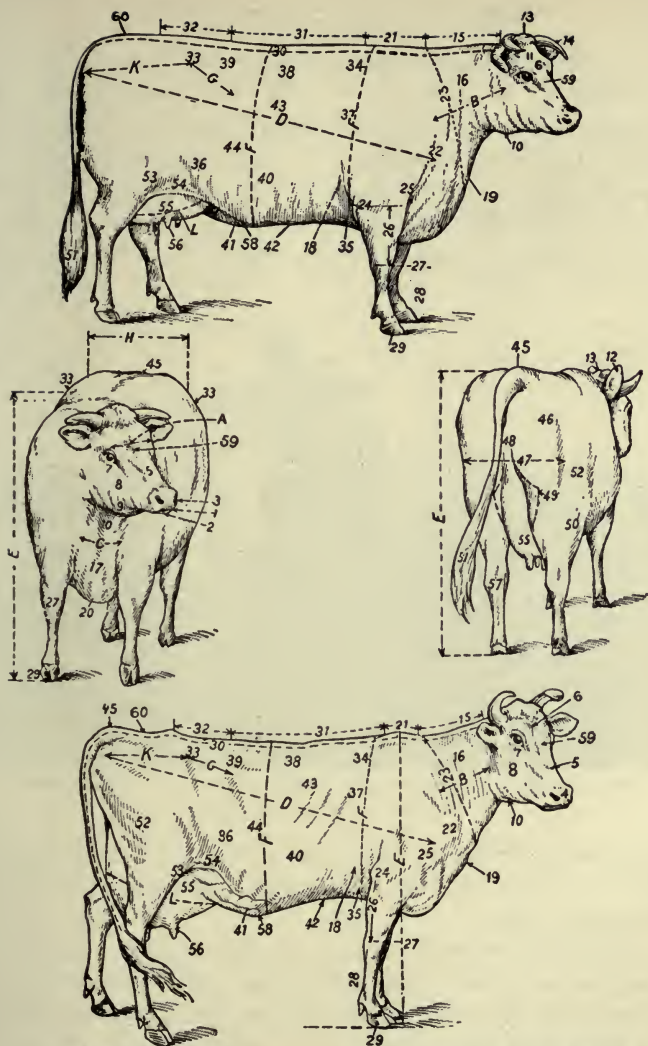


Fig. 132. Points and measurements to be observed in judging cattle.

and white, sometimes the white, sometimes the black, prevailing. In quantity of milk this breed excels all others. Colantha 4th's Johanna (Fig. 125) is credited with 27,432.5 pounds of milk in twelve months, which is the world's record. A good cow is expected to produce from 7,000 to 9,000 pounds of milk in a year. A cow that does not produce 4,000 or 5,000 pounds of milk a year is likely to be unprofitable. While the



Fig. 133. "She is broad on top." Courtesy of Department of Agricultural Extension, University of Ohio.

milk from Friesian cows is not so rich as that afforded by the Jerseys and the Guernseys, the total butter-fat is equally great.

275. Dual-purpose Breeds are intermediate between the beef and dairy types. The cows afford considerably more milk than the calves can use, and the body form is such that they dress out a good quality of beef. The breeds most usually classed as dual-purpose ani-

mals are Red Polls, Brown Swiss, Shorthorn and Ayrshires.

276. Judging Cattle. To become a good judge of stock one should study to find out the form and habits that represent useful qualities. The diagram in Fig. 132 should be closely studied, with two or three animals at hand for comparison, in training the judgment on the useful points.

Cattle should be judged for the use that is to be made of them. Where one is selecting "feeders," animals having the beef-type conformation will be more profitable. The person who has studied and practiced judging beef cattle will be able to quickly recognize the animals lacking in depth of body, quietness of disposition, or in what the butcher calls "quality," i. e., fine bone, soft, mellow hide, and silky hair. The animal with long legs, shallowness in depth of body at heart girth, and light in flanks, will rarely make a good feeder. Likewise, in selecting dairy cows, one comes to recognize certain habits and peculiarities of conformation that distinguish animals of special merit for dairy purposes.

CHAPTER XXVIII

TYPES AND BREEDS OF HORSES

277. Prehistoric Horses. The skeletons of horses existing in prehistoric times, ages and ages ago, are found in western North America, from Texas to British Columbia, also in England and France. Some of these early horses had toes. The little horny thickenings of



Fig. 134. Prehistoric horses. To show increase in size. A and B, Early forms; C, a later and larger form, about four and one-half hands high; D, the "forest horse." Drawings constructed from a study of the geologic remains, by Professor Osborne



Fig. 135. Trotting stallion, Carmon, 32,917. The first sire selected for use in the experiments of the Department of Agriculture to develop an American breed of carriage horses.

the skin just above the knee of the front legs (chestnuts) and below the fetlock of the hind legs (ergots) are marks of the toes that were in the feet of the prehistoric horses. The horses which we have now are thought to have descended from the Old World stocks. (Fig. 134.)

278. Valuable Qualities in Horses. The horse is invaluable on the farm or in the city. He is stout, quick, intelligent, and more faithful than any other animal used for bearing burdens. Horses and mules are necessary for heavy hauling and plowing. Other forms of power are cheaper or more desirable in many cases, but there will always be work for the horse.

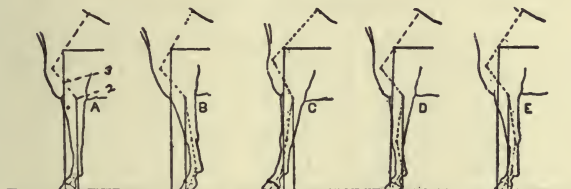
279. *Horses Should Be Selected for the work they are to do. Different kinds of work require different kinds of horses. A horse is of no particular value except for what he can do. To fulfil his mission he must travel. If he can draw a buggy containing one or two persons at the rate of ten miles an hour, he is valuable as a roadster. Another horse that can draw his share of a load weighing upwards of a ton, even though he moves slowly, performs an equal amount of actual work, and is just as useful to his owner as is the roadster. Since all horses are valuable because they travel, although at various rates and under widely varying conditions, it will be interesting to make a study of those parts of the horse's body directly connected with his locomotion.

280. Use of the Muscles. It is not difficult to understand that, with the horse as with ourselves, all motion is the result of the action of the muscles. About 40 per cent of the weight of an ordinary horse is muscle. All muscles concerned with locomotion are attached to bones, and when they contract they cause the bones to which they are fastened to move. The lower part of a horse's legs are nearly all bone, but the muscles in the body and upper part of the limbs are attached to various parts of the bony construction by tendons, and can thus produce a motion of the parts located some distance away. When contracted, the muscles we are discussing are about three-quarters as long as when at rest. The amount of motion produced by the action of the muscles of, say one of the horse's legs, will depend upon the length of the muscles and the

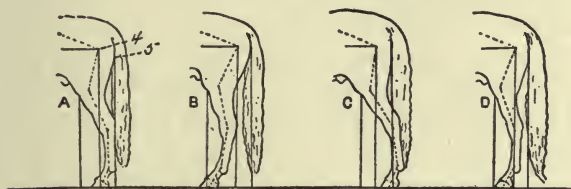
*Paragraphs 279 to 285 are taken by permission from a leaflet on "The Horse," by Prof. F. R. Marshall, published by the Ohio State University.



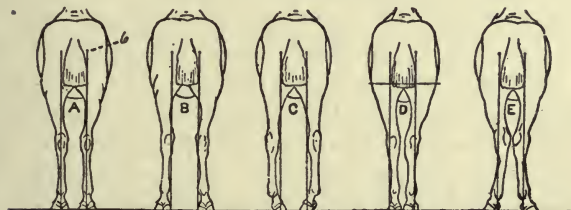
Front view of front legs. A shows correct conformation; B to G, common defects.



Side view of front legs. A shows correct conformation; B, foot too far back; C, too far forward; D, knee-sprung; E, knock-kneed.



Side view of hind legs. A shows correct conformation; B to D, common defects.



Rear view of hind legs. A shows correct conformation; B to E, common defects.

Fig. 136. Positions of horses' legs, while standing. After Craig.

length and the relation of the bones to which they are attached. The common idea among students of this subject is expressed in these words, "Long muscles for speed, short muscles for power." We have already seen that a long muscle enables a horse to get over ground rapidly. A short muscle, however, is not powerful because it is short, but because in horses constructed on that plan the muscles are thicker, containing more fibers, all of which pulling together when contracted exert a much greater pulling force than will a long, and more slender muscle. It is because of this that in buying horses to draw heavy loads we look for large and heavy muscles, while in roadsters we must attach importance to the length of the muscles.

281. Muscles of the Hind-quarters. The most of a horse's muscle is in the hind-quarters. This may be a surprise to you, but the next time you have an opportunity to see a horse pulling a very heavy load, study him carefully. You will be impressed with the idea that most of the work is being done with the hind legs. When the hind foot is moved forward the toe rests on the ground, and the leg is bent at the hock joint; if the toe does not slip, and the horse is strong enough for his load, the muscles above, pulling on the tendon fastened to the back and upper point of the hock, will close the joint, or, in other words, straighten the legs, and cause the body to move forward. It is by the performance of this act at every step that the horse moves, although, of course, the strain on all the parts is much greater when pulling very hard. This will also show the necessity of having large, broad, straight joints, and legs that give the horse the most secure footing. You have probably also noticed when driving that many

horses put their hind foot on the ground in front of the mark left by the fore foot, and the faster they go the greater will be the distance between the marks made by the fore and the hind feet. This shows that the length of a step is determined by the hind-quarters; it also explains the need of large, strong hocks, and legs that are not so crooked as to seem weak, or so straight as to lessen the leverage afforded by this very wonderful arrangement of the parts.

282. Body Form. Then there are some other things that are desired in all kinds of horses. One of these is a short back, that is, short from the hips to the top of the shoulders (the withers). From what we have learned of the hind parts we know that the horse is really pushing the rest of his body along. If the back is short and strong, instead of long and weak, the whole body will move more easily and rapidly in obedience to the force produced in the hind parts.

283. The Fore-legs. Although the hind parts have most to do with the horse's traveling, we must not forget that the front parts are also very important. No matter how much muscle a horse has, or how strong his hocks are, if there is anything seriously wrong with his front legs, he cannot travel, and so derives no benefit from his good parts. Some horses may be seen whose knees are not straight, others, when looked at from in front, show that their feet are not in line with their legs. Such animals are more likely to strike one leg with the opposite foot, thus making themselves lame and unable to do any work.

284. Horses' Feet. There are a great many interesting things about a horse which cannot be told here, but which you may learn at home, or from some neighbor

who keeps good horses. We will, however, say something about horses' feet. Inside a horse's hoof there are some very sensitive parts, resembling the attachment of the finger-nail to the finger. When anything gets wrong with the foot, these parts cause a great deal of pain, and even though the horse is otherwise perfect, the pain in his feet makes him too lame to travel. Horses with large, wide feet, that are wide across where they touch the ground when you look at them from behind (or in the heels), are not likely to have this trouble.

285. Style in Horses. Even though you have never studied horses, you have seen some that impress you as being more beautiful than others. No matter what kind of work is to be done, it is desirable to have a horse that looks well. Of course, it will depend upon whether the horse is thin or fat, and upon the grooming he has had, but you will usually find that the horses which attract you have rather long necks that rise upward from where they leave the body; the head, too, instead of being set on straight up and down, will have the nose pointed a little forward; the ears will be rather close together, and the eyes large and bright-looking.

286. The Draft Type is becoming more popular wherever horses are used. They are better suited to farm work and the heavy hauling of large cities. Good draft horses have large size, blocky build, short legs, broad backs and quiet tempers. Percherons, Clydesdales, English shires and Belgians are leading representative breeds of the draft type.

287. The Percheron is now the most popular draft breed in America. They are docile, intelligent, active, and have excellent feet; are heavy in weight, and

steady pullers under load. Typical specimens of this breed run from fifteen to sixteen hands high. The color is generally gray, though blacks are often met.



Fig. 137. Percheron, Medoc, 30,986. First in class at Iowa, Minnesota, and Wisconsin State Fairs, 1903; also one first and one second at Chicago International, 1903.

288. The Clydesdale is the recognized draft breed of Scotland, taking their name from the river Clyde. Usually they have smaller bodies and longer legs than the Percherons, which is supposed to allow more action.

289. Coach Types are sometimes referred to as heavy harness horses. The most popular breeds are the

Hackney, or English Coach, Cleveland Bays, French Coach and German Coach.

290. **Saddle and Driving Horses** are very popular because of their quick action. There are several strains



Fig. 138. Clydesdale mare, Princess Handsome. Winner of first prize three years in succession at Chicago International Live-stock Show.

of driving horses, all derived in part from the Arabian horses. As a result of superior breeding, the English thoroughbred and the American trotting horses have come to be better movers than the original Arabian stocks. There are several strains of the American trotting horses, such as the Hambeltonian, the Wilkes and the Morgans. The native "Mustangs," found in western

America by the early explorers, are supposed to be the descendants of early importations made during the Spanish conquest of Mexico.



Fig. 139. Hackney horse, Lord Burleigh. One of the greatest of modern show horses

291. Ponies. Besides the ponies owned by the Indians of America, the little Shetland island horses are called ponies. These "Shetlands" are small because they have been forced to live on the coarse and scant grasses of the cold regions of north Scotland.

292. Judging Horses. Fig. 136 illustrates the proper and improper position of the legs of horses. In studying horses this should always be closely observed. Get two horses together and closely contrast the various points. Fig. 140 gives the names in common use for the various parts of a horse.

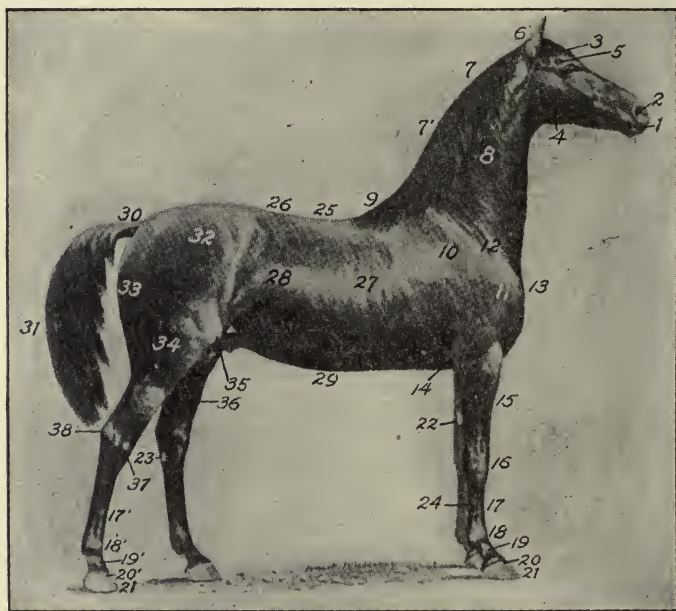


Fig. 140. Typical horse, showing names of the points.

- | | | |
|--------------------------|----------------------|--------------------|
| 1. Muzzle. | 14. Elbow. | 27. Chest. |
| 2. Nostril. | 15. Fore-arm. | 28. Flank. |
| 3. Forehead. | 16. Knee. | 29. Belly. |
| 4. Cheek. | 17-17'. Cannon bone. | 30. Tail head. |
| 5. Temple. | 18-18'. Fetlock. | 31. Tail. |
| 6. Poll or nape of neck. | 19-19'. Pastern. | 32. Croup. |
| 7-7'. Crest. | 20-20'. Coronet. | 33. Buttock. |
| 8. Neck. | 21. Hoof. | 34. Thigh. |
| 9. Withers. | 22. Chestnut. | 35. Stifle joint. |
| 10. Shoulder. | 23. Ergot. | 36. Gaskin. |
| 11. Point of shoulder. | 24. Splints. | 37. Hock. |
| 12. Slant of shoulder. | 25. Back. | 38. Point of hock. |
| 13. Breast. | 26. Loins | |

293. Care of Horses. Horses are intelligent and nervous animals, and should be handled with impassive judgment. Your treatment should convince him that you are his friend, as well as his master. If a horse shies, or becomes frightened, soothe and encourage him. You cannot whip terror out of a horse, nor courage into one. Before you check a horse's head into an unnatural position try it on yourself. Read "Black Beauty," and the story of the Bell of Justice in Longfellow's poem, "The Bell of Atri." Horses respond to care and kind treatment more quickly and decidedly than any other domestic animal, unless an exception be made in favor of the dog.

The horse has a small stomach, and therefore may not take in large quantities of feed at any one time without injury. The feeding of horses, for this reason, should be frequent and regular.

CHAPTER XXIX

TYPES AND BREEDS OF HOGS

294. Some Hogs Should Be on Every Farm. Hog flesh may be produced more cheaply than other kinds. There is very little waste in a hog carcass, because they are built so compactly. Hogs "dress out" seventy or eighty-five pounds of palatable products per hundred pounds live weight, varying according to the condition and kind of animal. With hogs, meat-producing quality is the valuable feature in all breeds. We consider not only the gross weight, but the form that will dress out the greatest per cent of high-priced cuts, and a small per cent of waste.

295. Food of Hogs. The hog will eat many kinds of slops and waste products that no other animal will. A range or pasture, clean, roomy pens, and some grain feed, with shelter for hot or extreme cold weather, are necessary to keep hogs healthy and growing. Some pasture should always be provided for hogs in winter

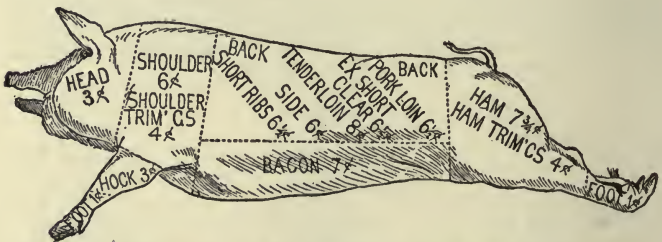


Fig. 141. Comparative values of the different cuts as used by the retail butchers of Chicago.

and summer. Oats, rye and wheat make good winter pasturage.

296. Lard Hogs. The hogs with large, spreading hams and shoulders, short bodies and broad backs, thick neck and jowls, with deep layers that contain a large amount of lard-bearing tissue as compared with the lean cuts, are called lard hogs. The Poland-Chinas, Berkshire, Duroc-Jerseys and Chester-Whites belong to this class.

297. Bacon Hogs are long in body, deep in sides, with comparatively narrow back, narrow, light hams



Fig. 142. Three representative Duroc-Jerseys.

and shoulders, and light, muscular neck. They lack the deep layers of fatty tissue found in the lard hogs. They have a strong muscular development, and hence dress out a large percentage of lean meat. Bacon hogs furnish a large proportion of the expensive cuts, such as choice hams and breakfast bacons. The Yorkshires and Tamworths are the leading breeds belonging to this class.

298. Duroc-Jersey. The Duroc-Jersey breed has probably descended from several strains of red hogs. The hair is coarse, and ears lopped forward. The back is



Fig. 143. Three representative Poland-Chinas.

short, slightly arched, and supports a broad, well-rounded body. The shoulders and hams are very heavy and thick-fleshed. Duroc-Jerseys are splendid feeders and good grazers and are justly popular in all sections.

299. The Poland-China breed is a native of Ohio. The color is black, with white points on feet and head. The ears are lopped, jowls are large, and the back has a gradual yet moderate arch the entire length. The body is shorter, but more spreading than in the Berkshire. As a rule, the sides and hams contain a smaller percentage of lean meat than the Berkshires. The pigs of this breed mature early, and as feeders under confinement, are rated among the best, and are especially liked



Fig. 144. Three representative Berkshires.

in the corn-belt states. They are typically representative of the lard-hog type.

300. Berkshires take their names from a shire, or county, of England. Berkshires have erect ears, a black body, generally with a white streak in the face, or jowl, and four white feet. The back of the Berkshires is nearly straight, with moderate breadth. The barrel is long, with slightly arched ribs and deep sides. They are strong and active and are good grazers. The Berkshire is a good feeder and affords a good quantity of bacon.

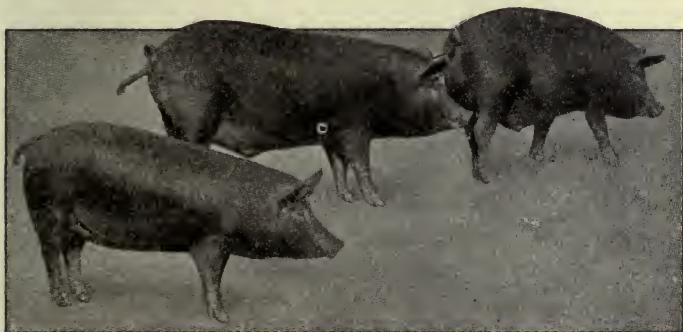


Fig. 145. Three representative Tamworths.

301. Tamworth. The native home of the Tamworth breed is in the counties of central England. They are typical of the bacon type of hog, so popular in some sections of England and Canada. With the increasing high prices for fancy bacon, they are becoming more widely recognized than ever before. The color is red. The back is long, while the sides are moderately deep and contain a large amount of "streak-o'-lean" bacon. The hams and shoulders are without the large amount of external fat so noticeably present in Poland-Chinas and Duroc-Jerseys.

CHAPTER XXX

TYPES AND BREEDS OF SHEEP AND GOATS

302. Uses. Sheep and goats are valued for wool and mutton. In some countries goats are kept not only for mutton and hair, but to supply milk. Sheep and goats are great grazers. They will make more out of a pasture than any other class of animal, consuming not only the grass, but also many of the weeds and leaves of shrubs. Sheep are grown in large herds in the western states, primarily for wool. In recent years many farmers in the South have found small flocks of sheep or goats valuable additions to the stock of their farms.

303. The Wool produced by the different breeds differs much in quantity, quality and character. In some strains of the Merinos the clip of wool may equal one-fourth or even one-third of the animal's gross weight. The wool is much less in the mutton breeds. The breeds



Fig. 146. Merino sheep. Champion flock at St. Louis Fair, Illinois State Fair, and Charleston, S. C., Exposition, 1902.

are usually divided into three classes, according to the length of the wool. The long-wooled breeds are represented by the Lincoln, Leicester and Cotswold, while



Fig. 147. Grand champion car-load of mutton sheep. Chicago International Exposition, 1901.

the short-wooled class includes the Southdown, Shropshire and Cheviot. The fine-wooled breeds are represented by the Rambouillet or French Merino, and Delaines or Spanish Merino. The fineness, as well as length of staple, is an important quality in wools. Dense fleeces, referring to the number of fibers per square inch, are desired by both the manufacturers and the sheep breeders. The dense fleeces afford more protection to the body, and deteriorate less from exposure to the rain, cold and dirt than the thin fleeces.

304. The Merino Breeds have descended from old Spanish stocks. They represent the highest type of wool producer. The fleece is fine, dense on the body, and uniform in length. The oil, or yolk, on the fleece causes the wool to catch a great deal of dirt on the outer layers, giving the animal a dark color. The Merinos are hardy, healthy and excellent foragers. They thrive even when the range is poor.

305. Mutton Breeds. The mutton qualities in sheep correspond to the same set of characters associated with the beef breeds of cattle. (See ¶ 268.) Sheep dress out from 50 to 60 per cent of their live weight in marketable prod-



Fig. 148. A famous Angora goat.

ucts. The leg, rib and loin cuts include nearly three-fourths of the total weight, and over 90 per cent of the value. Thus it is plain that a good mutton sheep means one with a blocky form, full, heavy legs, deep body, level, broad back, and short head and neck.

306. Goats. Goats are natural browsers, and not

grazers. They prefer the slender tips and twigs of young trees to grass, and on this account are often used to keep down the underbush in pastures. In the Southwest they find a climate well suited to their habits. The fibers of the fleece are very long and some coarser than fine wool. The fleece of the Angora goats is known as mohair. Milking breeds of goats have been highly developed in some countries. In the island of Malta the inhabitants depend very largely on goats for supplies of milk and butter. Milking-goats have been bred for centuries in Switzerland. Fine specimens give from four to seven quarts of milk a day.

CHAPTER XXXI

FARM POULTRY

307. Poultry Should be Raised at Every Home. Only a small outlay of capital is required to establish a paying poultry business. The natural food of nearly all members of the bird family is largely insects, small animals and fish. The eggs of all sorts of poultry are a rich, nutritious food. Ducks and geese produce a fine quality of feathers as well as eggs for food.

308. Hatching and Rearing Poultry. The growth of the germ in the egg begins at a temperature just a little below that of the bird's body. The temperature of the blood in chickens is given as 107.6° Fahr. or 42° C. In the brooding season the small blood-vessels on the breast of the chicken become more prominent. The time required to hatch, called the period of *incubation*, will vary with the freshness of the eggs and the kind of birds. The period of incubation for several kinds of birds is as follows:

Canary bird.....	14 days
Pigeon.....	18 days
Chicken.....	21 days
Guinea.....	25 days
Duck, geese and peacock	28 days
Turkey	28 days

309. Artificial Incubation. Artificial incubation is a very old practice in some countries. Incubators have become common in recent years wherever much

attention is given to the raising of poultry. It costs a great deal less to hatch, say, one hundred eggs artificially than it does to feed seven or eight hens. The additional advantage claimed for the incubator is that the

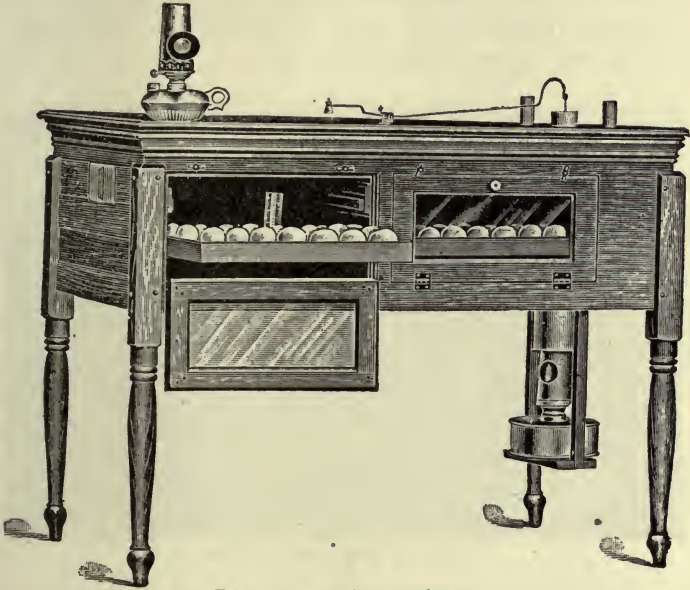


Fig. 149. A modern incubator.

hens soon begin laying, and that the chickens can be more easily cared for in brooders. There are two classes of incubators on the market,—the water-heated and the dry-heated. (Fig. 149.)

310. Poultry-Houses and Grounds. Poultry-houses and yards should be located on well-drained, and, preferably, on loose, sandy soils. They should be cleaned regularly to prevent the accumulation of filth that

might harbor disease-producing germs and parasites. The litter in the nests should be changed often. A dust box should be in every poultry-yard. The poultry-house may be simple in our climate, providing only a good coop, with the north and west sides closed, leaving the south wall partly open. The perches and nests should not be very high. (Fig. 150.)



Fig. 150. A simple poultry house.

311. Feeding Poultry. The natural food of all domesticated fowls, and, in fact, of nearly all birds, consists of insects, seeds and grasses. They require plenty of nitrogenous feeds, like insects, meat scraps, etc. For confined fowls, cottonseed meal, milk, or the tankage from the slaughter-house, make an excellent substitute for the animal feeds. Any of the grains may be fed to poultry. Green feed is very desirable for laying hens. All birds require grit to assist in the grinding of the feed in the gizzard. Coarse, sharp sand, crushed stone, or

cinders, etc., are desirable forms of grit. Crushed oyster-shells, or bones, supply the material for making the bones in young growing chickens and the egg-shells for laying hens.

312. Improving Poultry. To improve a breed or flock of poultry, use the eggs from the individuals having the desired characters. In breeding for increased egg-production, the number of eggs laid by a hen in a year is of far more importance than the color of the feathers. A hen laying 200 or more eggs a year is worth many times more than one laying from 30 to 50. There are many poor layers in all flocks. By using trap-nests for a full-year test the Maine Experiment

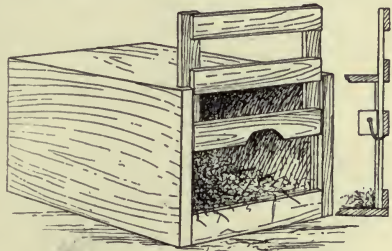


Fig. 151. A home-made trap-nest.

Station found that in a number of spring pullets all bred pure to type, only 3 laid more than 200 eggs; 10 laid 175 to 200; 11 laid 150 to 174, and so on down; 11 laid 75 to 100; 6 laid 50 to 75, and 5 laid 36 to 49.

In the development of the breeds of poultry, much attention has been given to perpetuating the color and character of the feathers, combs, wattles, etc. In recent years, greater efforts have been made to strengthen the more important qualities, such as regularity and frequency of laying, early maturity and other qualities, depending on the kind of poultry.

313. Preserving Eggs. Eggs decay as the result of the growth of germs in the rich substances of the egg. Warm temperatures favor the rapid development of

the germs, hence eggs decay much faster in the summer. Just how the germ makes its entrance through the shell is not fully understood. Of the many kinds of egg-preservedatives, none are so satisfactory as sodium silicate, commonly called "water-glass." The eggs may be packed away in a solution of about one part of water-glass to



Fig. 152. White Leghorns—popular representatives of the egg-laying, or Mediterranean class.

twelve parts of clean boiled water and kept as long as desired. A mixture of salty lime-water is often used. In either case, the egg-shell should be punctured with a needle before boiling to prevent the shells cracking when placed in hot water.

314. Classes of Poultry. There are many classes and breeds of poultry, such as chickens, turkeys, ducks, geese, guineas, pigeons and peacocks. Some are raised largely for eggs, others for meat or feathers, and others still to satisfy a fancy. There are two well-marked types of chickens,—the laying type and the meat type. A combination of the two gives the general-purpose type.

315. Egg Breeds. The so-called egg breeds are natives of countries bordering the Mediterranean sea. They are of medium size, good layers, but often poor sitters when young. They are easily frightened, very hardy, active and make good foragers. The most popular representatives of this class are the Leghorns, Minorcas and Hamburgs.

316. The Meat Breeds are natives of Asia, hence are sometimes called the Asiatic breeds. They are large, heavy bodied, slow moving, having a gentle disposition, and are persistent sitters and good mothers. They are generally considered poor layers, though the pullets are often excellent



Fig. 153. A Light Brahma cockerel. Typical representative of the Asiatic class.

layers. They are especially desirable because of the large size of the "broilers" and "friers." The best-known representatives are Brahmas, Cochins, Langshans and Faverolle, the latter a French breed.



Fig. 154. Barred Plymouth Rocks. Favorites of the flock having their pictures "took."

317. The General-purpose Breeds, such as the Plymouth Rocks, Wyandottes and Dorkings, are usually of fair size, furnish meat of good quality, and will produce a liberal quantity of eggs under favorable conditions. It has never been found possible to completely combine into a single animal the milk and butter-fat qualities of the dairy types of cattle with the meat-forming qualities of the beef breeds. The same body cannot be made to do both kinds of work to the same degree of perfection. So in poultry, we may blend, but cannot combine the egg- and meat-producing qualities. In selecting a breed, one should first decide what class of chickens will give the greatest return under the conditions,—a special-purpose egg or meat breed, or a

blend of qualities. The general-purpose breeds have good egg-producing power, and produce good-sized friers and broilers. They are often used for mothers for the egg breeds. (Fig. 157.)

318. Other Classes of Poultry. On many farms ducks and geese are raised for meat and feathers. There are great differences in the adaptability of the breeds. Ponds of water are not essential for success with this class of poultry. The food should be given to these birds in a soaked or softened condition, because their crops are less perfectly developed than in chickens, hence do not thrive so well on hard grains.



Fig. 155. Turkeys come home to roost.



Fig. 156. An effective method of confining a "cluck" and her "peeps."

319. Turkeys are native to North America. While they have lost much of their shyness and roving disposition by long association with man, they still must have the run of a large place for best success. The Bronze, White Holland and Black Norfolk are the most popular strains.

320. The Care of Young Poultry. Freshly hatched fowls of all classes are quite delicate and therefore call for special attention. It is important that they be kept warm and dry until the feathers are fairly well developed. Unless the mothers are confined at night, they will most likely lead the young chickens into the wet, dewy grass in the early morning hours. Nothing is so important as warm, dry coops and regular feeding in rearing young chickens, turkeys, ducks or geese. The feed should be specially prepared and offered five to seven times during the day. No feed is needed for the first day or two. The first food should be such as may be digested without grit,

such as ground grain or stale bread just well moistened in skim-milk. It makes little difference whether the milk is fresh or sour. They should be given no more feed than they will clean up promptly. The feed supplies to young chickens, and older ones as well, should contain ground bone or other form of mineral matter. It is not so important that they have animal food, as plenty of mineral



Fig. 157. The Plymouth Rocks are often used for mothers for Leghorns.

matter and protein. The latter may be of either vegetable or animal origin. Investigations for the cause of death among young poultry showed that 15 per cent had tuberculosis, due no doubt to imperfect sanitation; 38 per cent had intestinal troubles, and 75 per cent had diseased livers, influenced no doubt by unbalanced rations. (§ 335.) Shelter, feeding and exercise are points to be closely studied. The greatest losses which come to the poultry raiser are those due to disease in young stock—and, too, from diseases that can be prevented.

321. Judging Poultry. Fig. 158 shows the names of the more obvious points in chickens. The size, and colorings of the feathers are important points in distinguishing the different breeds. Purity in color markings does not always signify that the animal possesses the other qualities that are usually associated with the breed.



Fig. 158. Names of the points considered in describing chickens.

- | | | |
|---------------|------------------------------------|---------------------------|
| 1. Comb. | 9. Saddle-feathers. | 16. Primaries or flight- |
| 2. Face. | 10. Sickles. | feathers, wing-butts. |
| 3. Wattles. | 11. Tail-coverts. | 17. Point of breast bone. |
| 4. Ear-lobes. | 12. Main tail feathers. | 18. Thighs. |
| 5. Hackle. | 13. Wing-bow. | 19. Hocks. |
| 6. Breast. | 14. Wing coverts forming wing-bar. | 20. Shanks or legs. |
| 7. Back. | 15. Secondaries, wing-bay. | 21. Spur. |
| 8. Saddle. | | 22. Toes or claws. |

CHAPTER XXXII

NUTRITION OF THE ANIMAL BODY

322. Nutrition of the Animal Body. The nutrition of the body of the farm animals is through the same processes which have been previously described for the human body in the study of physiology. The feeds are taken in by the tongue and lips, masticated by the teeth, and digested in the stomach and intestinal canal.

323. Nutritive Substances. Animals require the same classes of *nutritive substances* to provide for growth, repair and waste as in the human body. The substances which are taken into the digestive tract are not available for the nourishment of the body until they have been rendered soluble, absorbed and become a part of the blood. The various cells of the body absorb the sugars, proteids, and salts directly from the blood. These substances are absorbed through the cell-walls, just as the yeast absorbs the sugar and albumen from the solution used in our early experiments. (§ 9a.)

324. Digestive Tract of Domestic Animals. There are important differences in the digestive tracts of the several classes of domestic animals, such that each is adapted to the different classes of substances upon which they feed and thrive.

325. Digestion by Fowls. Birds swallow their food whole without chewing. It passes first into the crop, where it is stored and softened by soaking. (Fig. 159 I.) Then it passes into the thick-walled, muscular stomach or gizzard. The gizzard is supplied with powerful

muscles which break up the food eaten by the fowls. This is greatly aided by the sharp gravel which fowls swallow.

326. Herbivorous Animals. Vegetable food must usually be eaten in greater quantity to furnish the needed nutrients. In herbivorous animals the intestine is not only of a great length, but often has a large and chambered stomach, furnishing a large laboratory

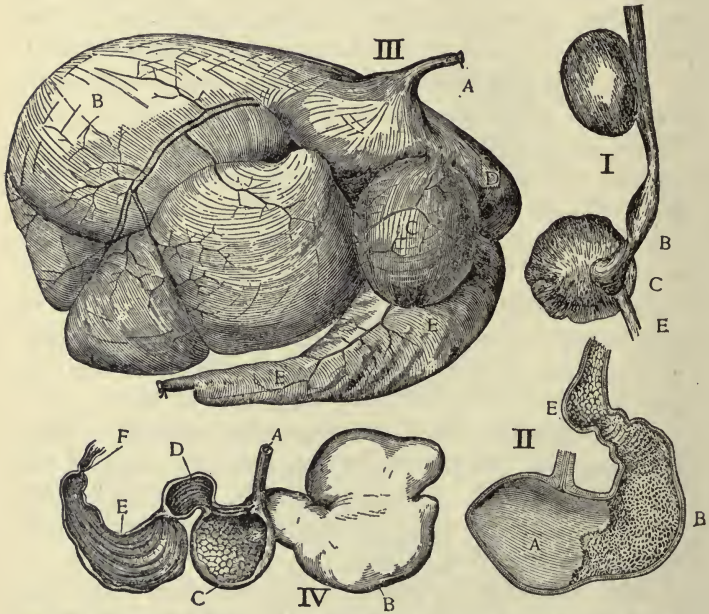


Fig. 159. Stomachs of some domestic animals. I, Crop and gizzard of fowl. B, glandular stomach; C, gizzard. II. Interior of horse stomach showing the two kinds of lining. A, left sac with tough white lining; B, right sac with soft red lining where the digestive juices are secreted; E, duodenum. III. Stomach of ox as seen from right upper face (Chauveau), and IV, Stomach of sheep with second, third and fourth divisions open. A, oesophagus; B' Rumen, or first division of stomach; C, reticulum; D, omasum; E, abomasum, or true stomach; F, duodenum.

in which the digestive processes may be carried out. In the stomach of the horse, which is comparatively small, two regions may be distinguished, of which only the right or second part secretes digestive juices.

327. Ruminating Animals. In cattle and all split-hoof animals, the stomach has four more or less distinct compartments. (Fig. 159 III and IV.) When a sheep or cow bites off a bit of grass, it is moistened with a small amount of saliva and swallowed without chewing, passing into the stomach, or paunch. The stomach is a mere store-house. After a time the animal finds a quiet place, regurgitates a ball of grass, called a cud, which is slowly ground up between the molar teeth. This mass is again swallowed and passes into the second stomach, and then on to the fourth or true stomach where the gastric digestion commences. Ruminating animals continue the digestive processes for a longer period, chew their food finer, and, in general, digest a larger per cent of the protein, carbohydrates, crude fiber and fat, than non-ruminants, like the horse.

328. Nutrients in Feeds. The animal must secure from the feeds consumed all the substances needed for the support and growth of the animal body. The undigested parts form the waste. The nutritive substances actually secured from the feeds are classed as:

1. *Proteids* (albumin, albuminoids, amides, etc.).
2. *Fats* (oils, fats).
3. *Carbohydrates* (sugar, starches, gums, celluloses).
4. *Mineral Matters* (salts of the elements found in plants).
5. *Water*.

329. Functions of the Nutrients. The two chief uses of the nutrients in animal feeds are to supply:

1. Building material for muscle, bones, skin, etc., and repair the waste.

2. Heat to keep the body warm, and to supply energy for work.

The several classes of nutrients act in different ways in fulfilling these functions. The proteids from the muscles, tendons, gristle, hair and hoofs supply the proteids of blood, milk and other fluids, as well as the whites and yellow in eggs. The chief fuel or heat-giving ingredients are the carbohydrates and fats. These are consumed in the body or stored as fat to be used as occasion demands. The proteids may supply energy, though it is not supposed that they do so in the presence of sufficient fats and carbohydrates.

330. Fuel Value of Feeds. Starches, sugars, and fats, are burned (oxidized) in the body and yield heat and power, just as the same substances would if burned in the stove to heat the house or under the boiler to make the steam for the engine. The heat or energy is developed gradually as the needs of the body demand. Scientists have ways of determining the fuel value of substances, and for the purpose of comparison use as the unit of measurement the calorie (equal to the heat required to raise one kilogram of water one degree Centigrade, or one pound of water four degrees Fahrenheit).

331. Digestibility of Feeds. The value of a substance as a feed depends not only upon the quantity of the different kinds of nutrients contained, but also upon how much of the nutrients are in a form that they can be digested and used for the support of the animal body. The usefulness of a substance for feeding depends, then, not on its gross weight, but upon the amount of building material and heat energy which the animal

may extract from it. In comparing feeding substances we should not only know the actual amount of proteids, fat, carbohydrates, etc., contained, but what per cent of these substances is digestible.

In some digestion tests at the Oklahoma Experiment Station with cockerels, it was found that 79.4 per cent. of the whole kaffir corn was digested, i. e., retained in the animal's body; in the same way 81.9 per cent of corn, and 64.1 per cent of cowpeas were digested.

332. Digestibility of the Nutrients. In the digestion tests mentioned above the composition of the substance fed, the nutrients digested and the waste, were as follows for each 100 grams consumed:

	Protein	Carbohydrates and fats
Nutrients in Kaffir corn...	11.88 grams	75.16 grams
Digested and retained	<u>6.28</u> grams	<u>73.09</u> grams
Undigested waste	5.60 grams	2.07 grams

In the above case it is noted that nearly all the carbohydrates were digested, though only about half of the proteids were used in the cockerel's body. Similar tests have been made for many kinds of feeds with many kinds of animals.

We see from this example that a chemical analysis giving the quantity of the nutrients is not an exact statement of the available nutrients. Appendix D gives the average results of many tests of the digestibility of American feeding materials. See also tables of composition in Appendix.

333. Ratio of Digestible Nutrients. In feeding animals it is important, as will be shown, to know the ratio of the digestible proteids, or flesh-forming nutrients, to the effective heat-forming substances. This ratio

is called the “*nutritive ratio*” and is taken to mean the ratio of the digestible proteids to the digestible carbohydrates plus 2.25 times the fat. (The fat has two and one-fourth times as much heat energy per pound as the carbohydrates.) Thus, in the preceding example, the nutritive ratio is 1:11.6, which means that the heat-producing nutrients are 11.6 times greater than the tissue-building nutrients.

EXAMPLE WITH COWPEAS.

	Proteids Grams	Carbohydrates Grams	Fats Grams
Nutrients in cowpeas.....	21.44	62.16	2.38
Digested and retained	8.68	55.30	2.24
Undigested waste.....	12.76	6.86	.14

Ratio for digestible nutrients is $8.68:(55.30+2.24 \times 2.25) =$
 $8.68:(55.30+5.60) =$
 $8.68:60.90 = \text{nutritive ratio } 1:7.01$

The ratio calculated according to the chemical composition is 1:3.1, which we see would be quite misleading, judging by the actual ratio of digestible nutrients, which is 1:7.01.

334. Application of Ratios. The ratio of flesh-forming nutrients to the heat-producing nutrients should be suited to the condition and requirements of the animal. Animals at heavy work, where the muscle materials are being used up, require relatively more proteids than when merely at rest. Likewise, young and growing animals require plenty of building material, or animals which produce substances like milk, eggs and wool—substances that contain large quantities of proteids—should have food rich in proteids. (See table E in Appendix.)

335. Economy of Balanced Rations. When the proteids and heat-producing substances are supplied in the ratio approximately in which they are consumed, the ratio is said to be "balanced." There may be wide limits in the nutritive ratio without impairing the general health of the animals, but there may be a great difference in the cost of properly nourishing the animal. The feeds rich in proteids are very expensive, and it is desired that they be used only in the formation of nitrogenous products, and never to supply energy. The cheaper starchy foods should be used in sufficient quantity to supply heat and muscular energy. Thus, we see that by knowing something of the composition and digestibility of the common feeds, we may combine them in such proportions that the animal may be properly nourished at small cost.

336. Kinds of Rations. Rations are classed according to their effect on the animal, as regards bodily weight or function. The most usual designations are:

(a) *Deficient ration* is one in which the animal loses weight.

(b) *Maintenance ration* is one which allows just enough to keep the animal in good health without loss or gain in bodily weight. This is usually about three-fourths to one pound of nutrients to the hundred pounds of live weight.

(c) *Growing ration* is one allowing of a regular gain in weight. The amount of feed which a young animal may profitably consume varies widely, usually from 2 to 4 per cent. of live weight.

(d) *Work ration* is one that will sustain an animal at work without loss of weight or vigor.

(e) *Dairy ration* is one that supplies the materials

for maintenance of bodily conditions, as well as those used in secreting the milk.

There are many other kinds of special rations, referring to the bodily needs of animals maintained under special conditions, such as egg rations, wool rations, etc.

337. Planning a Ration. Suppose it is desired to know how much and what kinds of feeds to give to a dairy cow of 1,000 pounds live weight, giving two gallons of milk per day. Turning to table of standard feeding requirements (Appendix F.) we have:

	Live weight pounds required	Total dry matter	Digestible nutrients		
			Pro- tein	Carbo- hydrate	Fat
Dairy cow, 16 lbs. milk..	1,000	27	2.0	11.0	0.4

The problem is to find the combination of feeds that will supply the above nutrients in approximately the amounts indicated. Suppose we have alfalfa hay, wheat bran and cottonseed meal. After studying the tables of composition and digestible nutrients as given in the Appendix, we may make a trial guess, with the result as follows:

Feeds	Amount	Dry matter	Digestible nutrients		Cost
			Proteid	Carbohy- drates, fat	
Alfalfa hay, dry.	10 lbs.	9.2	1.10	4.2	....
Mixed hay	10 lbs.	8.5	.44	4.4	....
Wheat bran	5 lbs.	4.4	.60	2.3	....
Cottonseed meal.	1 lb.	.9	.40	.4	....
Total	26 lbs.	23.0	2.54	11.3	....

The result shows that we do not have enough dry matter, and too much proteid by .54 pounds. The

latter is usually very expensive and would be advisable only when the alfalfa was very cheap. Suppose we decrease the alfalfa, increase the mixed hay, and leave out the cottonseed meal, which may be done when we feed rich nitrogenous hay, like alfalfa. Then we try:

Feeds	Amount	Dry matter	Digestible nutrients		Cost
			Protein	Carbohydrates, fat	
Alfalfa hay.....	5 lbs.	4.6	.55	2.1	....
Mixed hay	20 lbs.	16.9	.88	8.9	....
Bran	5 lbs.	4.4	.60	2.3	....
Totals	30 lbs.	25.9	2.03	13.3	....

The result is quite close enough. Close observation may suggest slight variations to suit the needs of different animals. It should be understood that these "standards" are averages, and that particular animals may require more or less than the amounts indicated.

338. The Amount of Feed required depends on the size and condition, and also on the individuality of the animal. By many carefully conducted trials, investigators of feeding problems have made approximations of the dry matter, protein, carbohydrates, etc., needed per hundred or thousand pounds live weight of animal per day. (See table of feeding standards in Appendix.)

339. Roughage and Concentrated Foods. According to the per cent of digestible nutrients in feed stuffs they are classed as *Roughage* and *Concentrates*. Substances like hay, which contain a large per cent of undigestible substance, are called Forage or Roughage, and those like the grains, cottonseed meal, etc., in which nearly all is digestible, are called Concentrates. Rough-

age is desirable to give bulk to the ration. Straw is an excellent roughage, yet if fed on straw alone, an animal would be unable to eat enough to secure the needed nutrients. If fed on concentrates entirely, the digestive juice could not act on all parts sufficiently and disorder would follow. Water and fiber give bulk to feeds. Ruminating animals require about two-thirds of their feed to be in the form of roughage. For horses, about one-half should be in the form of roughage.

340. The Food Should Be Palatable. The food supplied should be relished. A ration may be perfectly balanced, so far as its nutrients are concerned, and yet if it is not palatable, good results may not be secured. One way of making foods palatable is to give a change—change in hay or in concentrates. In changing from one kind of feed to another, however, the change should be made gradually. Abrupt changes in feed are likely to throw highly fed animals “off feed.” Animals relish variety at the dinner-table just as we do. The good effect of green feeds in winter time is probably due in part to this fact. Green feeds through the winter may be easily supplied in nearly all parts of the South by sowing fall oats or wheat. Green feeds aid the digestion of other feeds.

341. Importance of Salt for Stock. Every good farmer knows that his stock needs salt, and takes pains to supply them. All classes of farm animals should have salt where they can get it every day. Almost every animal will take salt every day. Either fine or rock-salt may be used, and, to prevent waste from rains, it should, if possible, be under a shed. Ruminating animals (sheep and cattle) need salt more regularly and abundantly than horses. Dairy cows should always

receive special attention in this respect. Salt aids digestion, improves the appetite, and lessens the danger from disease. Small quantities of salt in the feed will often stimulate the appetite of sick animals and acts as a good tonic.

342. Preparations of Feeds. The extent to which different feeds should be prepared by grinding, shredding, soaking, cooking, etc., before feeding is, in many cases, an open question. When grain is fed to ruminants it is best to have it milled, but in other cases it is frequently without advantages, except in the case of kaffir corn. Kaffir corn should be ground for all farm stock.

343. Racial Peculiarities are observed in the way different breeds dispose of the feed they consume above that required for maintenance. This is important. The manner in which an animal disposes of the feed above that required for maintenance governs the profit or loss in animal husbandry. It is this extra quantity of feed that makes flesh, milk, eggs, or performs work. If the maintenance ration be assumed to be eight pounds of dry matter and the feed contains twenty-five pounds, what becomes of the additional seventeen pounds of feed? The Hereford steer would deposit it in the loin steaks and thick quarters. The animals would gain in weight. The dairy cow would probably not gain in weight, but use it in making the fat, sugar and curd of milk. An animal is valuable for its ability to transform large quantities of crude farm feeds into special products, such as valuable cuts of meat, milk, wool, etc., or to perform labor.

344. Individual Peculiarities are also to be noted. The average dairy cow will profitably use about six pounds of feed above the maintenance ration. Many

animals will be able to profitably use only three or four pounds, while still others may return a profit on twelve or fifteen pounds. The intelligent feeder knows how to feed to get best results, but in every herd or flock there are "good feeders" and "poor feeders." The wise breeder notes the peculiarities in selecting his animals for propagation. "Like begets like," in habits as well as in form.

345. Skill in Feeding. The observant farmer or feeder will soon learn the peculiarities of his animals. He never feeds an animal so abundantly that the appetite will be lax at the next feeding. He will feed often and regularly. In fattening hogs, steers, etc., he begins with light rations, and increases gradually as circumstances suggest until the stock are on "full feed."

346. Pasturage. Wherever possible, provision should be made for stock to gather green food from pastures. It is a benefit to the fields to sow them in winter annuals and allow the stock to graze during dry weather. This is especially desirable for poultry, dairy cattle and hogs. In some cases it is profitable to haul the green feed to the stock, rather than pasture it. This latter practice is spoken of as "soiling" and the crop as a "soiling crop."

347. Shelter for Farm Animals. A simple shelter to shield stock and poultry from wet or cold weather is necessary on every farm. This need not be so elaborate and costly as those used in colder regions. Shelter reduces the cost of feeding. Exposure reduces the flow of milk in dairy cows and the frequency of laying in poultry.

CHAPTER XXXIII

FARM DAIRYING

348. Farm Dairying. The dairy cow on the farm is a necessity, first and foremost, because she supplies food for the family which in quality and cheapness is without comparison. Milk and eggs supply the protein nutrients needed by the human body cheaper than meats. A pound of steak, a dozen eggs, or a quart of milk supply about the same amount of protein, yet the selling price of the milk, on an average, is less than half the cost of the others. Milk and butter are not only important foods, but valuable condiments used in many ways in rendering other foods palatable. It is these qualities that make a market for dairy products the world over.

349. A Natural Advantage of the South is the ease with which green feeds may be grown throughout the entire year. Many dairies are profitable without green feeds, yet every one recognizes that fresh green feed, either in pastures or in soiling crops, is a great aid in increasing the flow of milk. Mild winters remove the necessity for expensive barns, and reduce the quantity of feed needed to keep the cow in splendid condition.

350. The Distinctive Quality of the Dairy Cow is her capacity to manufacture large quantities of milk, rich in butter-fat, from common feeds. A cow that does not give more than two gallons of rich milk per day should be discarded. The richness of the milk is always to be considered. The Babcock test (Fig. 160)

places easily at the disposal of every farmer a means of determining the butter-producing qualities of every cow in the herd. The success or failure of the farm dairy to yield a profit on the outlay for land, building, feed and labor, lies in the proper selection of the cows to compose the herd.

351. The Babcock Test is a simple means of testing the milk to determine the amount of butter-fat (richness) contained in a sample of milk. It takes its name from Professor Babcock, of the University of Wisconsin, who discovered the method of making the test. By its

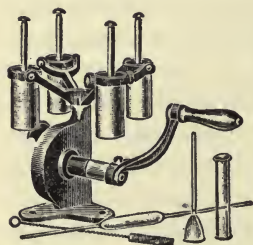


Fig. 160. Apparatus used in making the Babcock test.

use the dairyman may learn which of his cows pay for their board. The milk from each cow is weighed, and a small sample used to determine the per cent of butter-fat. Knowing these two facts, the total butter-yield for each cow may be calculated. In this way the value of the cow is definitely known. It is easier and more reliable than a "churning test."

In making the test, a measured quantity of milk is put into a special flask (Fig. 160), and to this a small quantity of acid is added. By following a few simple operations, for which directions come with every machine, the per cent of butter-fat is read off directly on the graduated neck of the bottle. Knowing the per cent of butter-fat and the quantity of milk, the amount of butter in each cow's milk may be quickly calculated.

352. How Dairy Cows Are Valued. The dairy cow is valuable according to her ability to convert farm feeds

into milk rich in butter-fat. Creameries and dairies pay for milk according to the per cent of butter-fat, and not the mere gallons of milk. (See Fig. 124.)

352a. (a) Farmer "A" runs a small butter dairy. He bought a Babcock Test, and made a test of each cow's milk with the following results:

Name of cow	Average daily flow of milk	Per cent of butter-fat in average samples	Pounds butter-fat daily
	Pounds	Per cent	
Blossom	23	2.3	.....
Flower	14	3.1	.....
Nancy	31	4.2	.....
Lily	20	6.5	.....

Calculate the amount of butter-fat in each cow's milk. One pound of butter-fat is equal to one and one-sixth pounds commercial butter. How much butter would these cows make in ten months?

353. Other Uses of the Babcock Test. Creameries no longer buy milk by the "gallon," but pay so much a pound for the butter-fat. This does away with the temptation to water the milk. In cities, public dairies are required to sell pure milk, with a certain amount of butter-fat, usually not less than 3.5 per cent. By the use of the test, both the dairyman and the public officials may easily know if the milk is up to the required standard of richness. The butter in buttermilk is often a source of considerable loss. By testing the buttermilk, or skim-milk, the dairyman may know if his methods get all the butter.

354. Composition of Milk. Milk contains about 87 per cent water and 13 per cent solids, divided as follows: 5 per cent sugar, 3.3 per cent protein, 4 per cent

fat and only 0.7 per cent mineral matter, or salts. The milk from different cows varies considerably. The solids may be as low as 10 per cent or as high as 18 per cent. The protein (the substance that thickens and forms clabber) may be low if cows do not receive feeds sufficiently rich in protein. The fat varies, sometimes as low as 2.5 per cent and sometimes as high as 8 per cent. The legal standard required by state and city laws is 3 to 3.5 per cent fat, and 9 to 9.5 per cent solids other than fat. The composition of milk is but slightly changed by the feed a cow consumes. The feed does affect the quantity of milk, however.

355. How the Kind of Feed Affects the Flow of Milk.

The feeding of dairy cows to increase the flow of milk has long been studied, both by the experiment stations and practical dairymen. The exact methods of scientific investigation where the feed consumed and the milk and butter produced are carefully weighed, teach that for the best results dairy cows should have:

(a) An allowance of green, succulent food, either by pasturing, soiling crops or silage.

(b) Some dry roughness in the form of hay, corn stover, or straw.

(c) Grains or concentrates supplying sufficient protein and carbohydrates to bring the ration to the normal dairy standard.

Succulent feeds promote the digestion of other feeds, and give flavor and color to the milk and butter.

Dry roughage has a wholesome effect on the health and general condition of the cows. The cow craves some dry feed which can be hastily swallowed, and while lying down at rest, be regurgitated and chewed over.

356. Changes in Milk. Bacteria are the active agents of change in milk. The souring of milk is due to the formation of acid by bacteria. When the acid accumulates in sufficient quantity, it combines with the protein to form the clabber. If bacteria are kept out of the milk, it will keep sweet indefinitely. The flavors developed in milk and butter are due to the presence of certain kinds of bacteria. Some give the butter undesirable flavor, and some greatly improve the flavor. The flavor of butter, however, may be controlled by destroying all the bacteria in the milk or cream by Pasteurization. (§ 367.) After the milk or cream has been freed from the desirable, as well as undesirable germs, by the process mentioned, it is then cooled and desirable ones

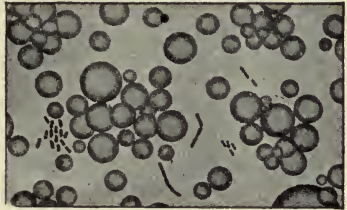


Fig 161. Microscopic appearance of ordinary milk showing fat globules and bacteria in the milk. The cluster of bacteria on left side are lactic acid-forming germs. After Russell, University of Wisconsin.

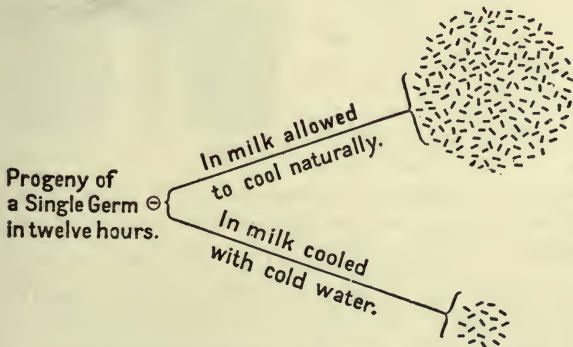


Fig. 162. Cooling hinders growth of bacteria. After Russell.

are added and maintained at a temperature favorable to the development of proper flavors and texture in the butter. This is preferably between 60° and 70° Fahr. This practice is known as adding a "starter," and is used extensively in commercial butter-making. In the absence of commercial starters, a little sour milk will prove quite satisfactory.

357. Gravity Creaming.

When milk is "set" to allow the cream to rise, it should be kept cool. The cream rises quicker and more completely if kept cool by ice or moist cloths. Gravity creaming leaves from 0.2 to 1.0 per cent of the butter-fat in the milk even when the temperature of the milk is kept at 60° Fahr. The rise of the fat globules of milk to form "cream" is due to the fact that fat is lighter than water or the milk serum.

Where circumstances make the purchase of a centrifugal separator inadvisable, resort must be had to gravity creaming. There are three methods of gravity creaming to be considered. The "shallow pan setting" involves the use of the conventional milk-pans about four inches deep. With favorable conditions of temperature, about 60° Fahr., one may count on leaving from



Fig. 163. A modern cream separator.

0.1 to 1 per cent of fat in the skim-milk. An average will be about 0.5 per cent. Very deep vessels are used in the "deep setting method." The latter will give a more complete separation where the temperature can be kept low, leaving only about 0.3 per cent fat in the skim-milk. Sometimes the "water dilution method" is used. The fresh milk is diluted with an equal volume of water before setting. This renders the milk unsuitable for domestic use, and, besides, has been found to leave more butter-fat in the milk than any system of gravity creaming.

358. Centrifugal Creaming. The cream separator is a machine for separating the cream from milk while fresh. It separates cream much better, quicker and with less work than gravity creaming. Good separators leave only 0.02 to 0.08 per cent of the butter-fat in the milk. The separator also gives a cleaner cream than can be obtained by the usual methods. The effectiveness of cream separators is due to the action of centrifugal force, which has a tendency to throw the heavier particles to the outside. Cream being lighter than skimmed milk, it is thrown to the center and the skimmed milk thrown to the outside of a rapidly revolving hollow ball.

358a. Farmer Smith milked ten cows, giving an average of 6,000 pounds of milk per year. He used the gravity creaming process and lost one-third to three-fourths pound of butter on every hundred pounds of milk due to imperfect separation of the cream. His neighbor advised the purchase of a cream separator which would leave only one-twentieth pound of butter-fat in the milk, telling him that besides saving the difference in butter-fat he would be able to feed his calves the fresh-skimmed warm milk. Estimate the difference and give your advice to Farmer Smith.

359. Sanitary Dairy Products. In the production of sanitary dairy products, great care must be observed

in the following particulars: (1) The healthfulness of the animals. (2) The healthfulness of the milker. (3) The cleanliness of the stables. (4) The care in milking. (5) The care in keeping the milk. Unless all of these conditions are carefully observed, sanitary milk-production is an impossibility.

360. The Healthfulness of the Animals. Unless the dairy cow is in a healthy condition, she should not be expected to secrete a healthy milk. All of the blood which goes to the manufacture of milk must pass through the circulation, and if any diseases are present the blood is apt to take up the germs producing them, and in some cases these same germs have been found in the milk. It will, therefore, be noted that the first essential in the production of sanitary dairy products is the presence of a healthy herd of cows.

361. The Healthfulness of the Milker. On account of the fact that milk is peculiarly adaptable to the growth of germs, any one having a contagious or infectious disease should not come in contact with it. Germs are always present in such cases, as smallpox, typhoid fever, diphtheria, etc., and are certain to find their way into the product if the person afflicted is permitted to come in contact with the milk or butter.

362. Cleanliness of the Stable. At best, the stable is difficult to free from bacteria. The great natural enemies of bacteria are light and sunshine. The stable should be kept clean, and there should always be present an abundance of fresh air and sunshine. The dark corners of the stable, filled with dust, are the houses of millions of germs which finally find their way into the milk and make it unfit for human food.

363. Care in Milking. When milk first comes from

a healthy cow, it is clean, wholesome, and free from bacteria or germs. It is also known that it is possible to produce milk with comparatively only a few germs by the exercise of care in milking. The care in milking consists in clean hands and clean clothes on the part of the milker, and the proper cleaning of the cow's udder before the milking begins.



Fig. 164. Revolving barrel churn.

364. Care in Keeping Milk. Milk is very susceptible to bad odors as well as germs, therefore it should be removed to a cool, clean place as soon as milked. The milking should precede the feeding, as there is always more or less dust present in feeding hay, and other undesirable odors are present when feeding silage or root crops. As soon as milked, the animal heat and

animal odor should be removed by thoroughly airing and cooling the milk.

365. Churning. The size, consistency and number of the butter-fat globules is not always the same. The object of churning is to cause these many, minute fat globules to unite to form larger ones. This is brought about by agitating the milk in such a way that the globules will rub against each other and unite. As temperature greatly affects the consistency of the globules it also affects the nature of the result in churning. If the temperature is very low, the globules are hard and are less likely to adhere in the operation of churning. If the temperature is very high, it renders the globules quite soft and churning has a tendency to cause them to break up into even smaller particles. There are many other conditions besides the temperature that affect the "gathering," or "breaking," of the butter-fat globules and the character or quality of the butter, such as the condition and breed of the cows, the feed of the cows, the temperature maintained during the ripening of the cream, the acidity of the cream and even the nature of the agitation given the cream in churning. As these conditions vary, so will the churning temperature. Practical dairymen usually try to maintain a temperature near 59 to 65 degrees in churning. The preference is usually for the lower temperatures because of the better quality of the butter, although it will require a longer time to churn. There are many styles of churns on the market, but expert butter-makers usually prefer some form of revolving box or barrel churn, claiming that it gives a butter with better quality. Where the agitation is produced by paddles the grain of the butter is not so desirable as in the open-centered churns.

366. Judging Butter. Butter is now judged by a scale of points just as the breeds of live stock and crops are. The points of most importance are (1) flavor, (2) texture, (3) color, (4) salt, and (5) package. Variations in flavor are due to several causes, such as breed of cows, individuality of cow, nature of feed, acidity of cream and kind of bacteria in the cream. Variations in texture are due chiefly to the nature of the feed and the temperature at which the cream ripens, and, also, the churning temperature, as discussed above.

367. Pasteurization. One way of keeping milk longer than could be done under natural conditions, consists in heating to a temperature of 160° Fahr. and then rapidly cooling. This method of treating milk is known as Pasteurization, and takes its name after Pasteur, the great French bacteriologist. The object of heating and cooling is to destroy the majority of bacteria present, and prevent the others which are not affected at that temperature, from becoming active. The temperature given above is deemed sufficient to destroy all, at least all disease-producing, germs and is not high enough to affect the flavor of the milk.

368. Clarification. We have just observed the practice of freeing milk from bacteria in order to make it "keep" longer. Now let us note the practice employed in freeing the milk from undesirable foreign matter. It matters not how careful the milker is in doing his work, there is always more or less foreign matter, which passes through a "strainer." This substance may be separated from the milk by centrifugal force. The process is known as clarification, and the machine used is known as a clarifier. The machine is built on precisely the same plan as a cream separator.

PART III—SPECIAL TOPICS

CHAPTER XXXIV

THE HOME LOT

369. The Decoration of a Landscape with herbs, shrubs and trees has been called "picture-making out-of-doors." Whether we know it or not, all of us have a great appreciation of the beauty and grandeur of landscapes. We recognize that some landscapes are attractive, or that the surroundings of some homes look bleak. Again, there is the little cottage of the new-



Fig. 165. Where shrubs are needed. After Waugh, *Landscape Gardening*.

comer, simple though it may be, yet we say, "It's a nice place." Ask us why, and the answer is a very uncertain one. Why? It's because we fail to recognize the essentials of a good picture. A good picture should suggest themes for pleasant, harmonious thought. "Believing, as we do, that the beauty and force of every true man's life or occupation depends largely on his pursuing it frankly, honestly, openly, with all the individuality of his character, we would have his house and home help to give significance to, and dignify that daily life and occupation by harmonizing with them."

370. Studying Landscapes. Compare Fig. 165 with Fig. 166. Manifestly, one is more pleasing to the eye than the other, but why? Some shrubs have been added, it is true, but it is not the shrubs in themselves that are so noticeably pleasing. The shrubs cover up many of the harsh geometrical lines and make the landscape look



Fig. 166. Where shrubs are added. Compare with Fig. 165.

more natural. Had the shrubs been placed in the open space the effect would not have been half so pleasing. The large open lawn gives an attractive setting for the trees farther on. A comparison of these two pictures teaches us the A, B, C of landscape art. In making

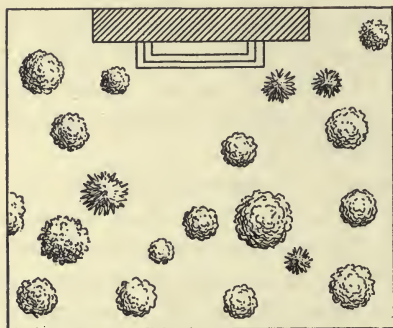


Fig. 167. A plan that brings the plants into prominence.

pictures on the landscape, whether around the home, churchyard, cemetery or the school house, we should

(A) Strive to avoid sharp, straight lines;

(B) Preserve broad, open spaces; (Figs. 167, 168).

(C) Plant in masses, and look to nature for instructive examples in arranging shrubs and trees.

371. Rural Home Grounds should have such groupings of lofty trees and attractive shrubs that the sharp lines of houses, barns and fences shall be softened into a natural picture. The appearance of the home lot should suggest more than mere shelter for man and his useful animals. It should appear as though the house, barns and lots were built in what was naturally an attractive landscape. Open lawns and large trees are always pleasing. In the crowded city such features may, from necessity, be dispensed with, but, when the country house is set in a small yard, it impresses us immediately as showing too great a contrast with the natural openness that is so characteristic of rural life.

372. Planning a Home Lot is a matter requiring much study. Along with the study of the view of the home site from within and without, we must cautiously plan for all the conveniences for the living of both man and beast. The location of the house, the barns, poultry houses, roads, gardens, orchards and fences should first be studied from the standpoint of convenience and healthfulness. When these features are planned, then we may study how to complete the picture and introduce those features that make a residence "home-like."

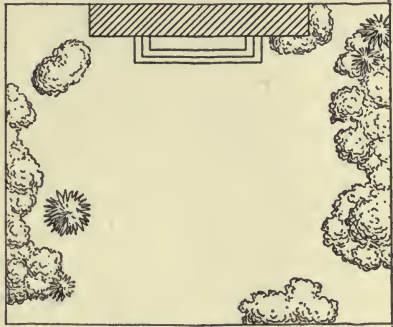


Fig. 168. A plan that makes a good picture, whether viewed from the house or the highway.

373. Completing the Picture. In placing the trees, shrubs and flower-beds, we should consider first the outlook from the house,—the view that we will see most often. Next we may consider the view from the highway. In both cases the openness of view should be preserved. In planting the trees and shrubs we are using them only as materials. They may make or mar the view, according to the way we arrange them. (Fig. 169.)

374. Locating the Plants. In making a plan, the grouping of the plants should be carefully worked out. For every plant to be used, we must know how it will look, and how much space is required when fully mature. After a satisfactory knowledge of the plants has been gained, we may mark the place for each on our plan

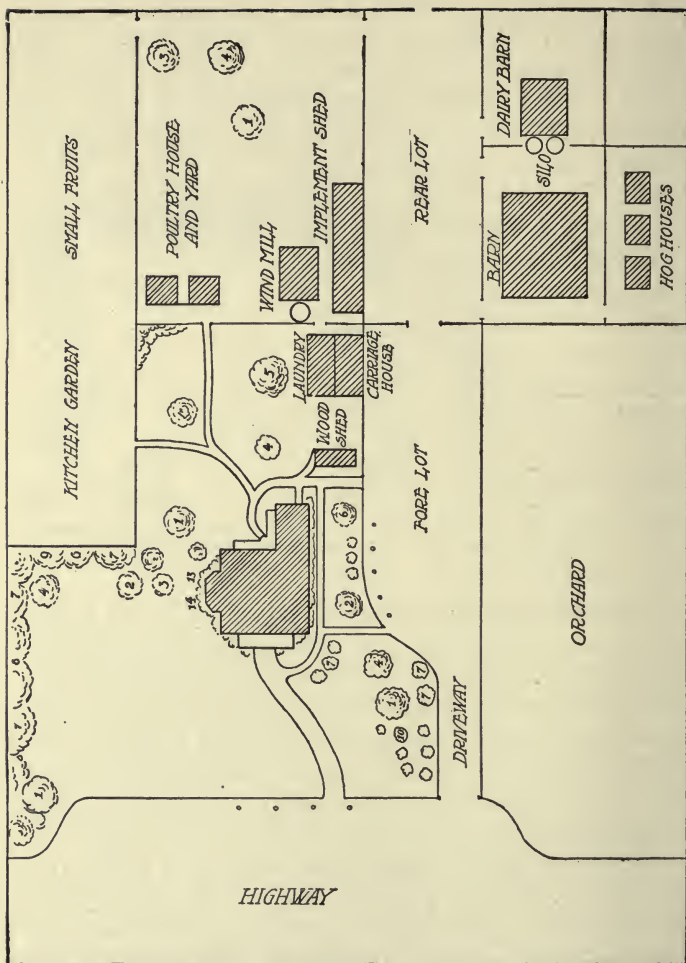


Fig. 169. A good plan for the arrangement and decoration of a farm-house, buildings and grounds. Make a list of the trees and shrubs of your locality that would be suitable for the above.

(Fig. 169). The way the plants are grouped makes a great difference in the appearance of the place. Every attractive picture has some one central object. In making a picture on the landscape, the home, or the school-house is to be made the central feature. As a picture is often marred by a poor frame, so may a landscape lose its attractiveness by improper use of plants.

375. Plants to Use. Landscape architects are also gardeners in that they must know the character of many kinds of plants and the conditions under which they succeed. In selecting trees and shrubs for home planting, it is important that sorts be used that succeed. Native wild plants should always be considered. Often much time, labor and money are wasted in trying to grow foreign plants unsuited to the climate or soil. Many native or wild plants give splendid results when planted in well-prepared ground. By observing the plants that are grown on other persons' grounds, we may often learn of the good sorts and avoid undesirable varieties. In selecting the plants, it is always advisable to consult the local nurseryman.

375a. Make a list, using the names given in the nursery catalogues, of all the different kinds of trees, shrubs, perennial and annual flowers that grow well in your locality. Mention the location in the community of one or more plants of each sort. Do not forget to consider the native plants.

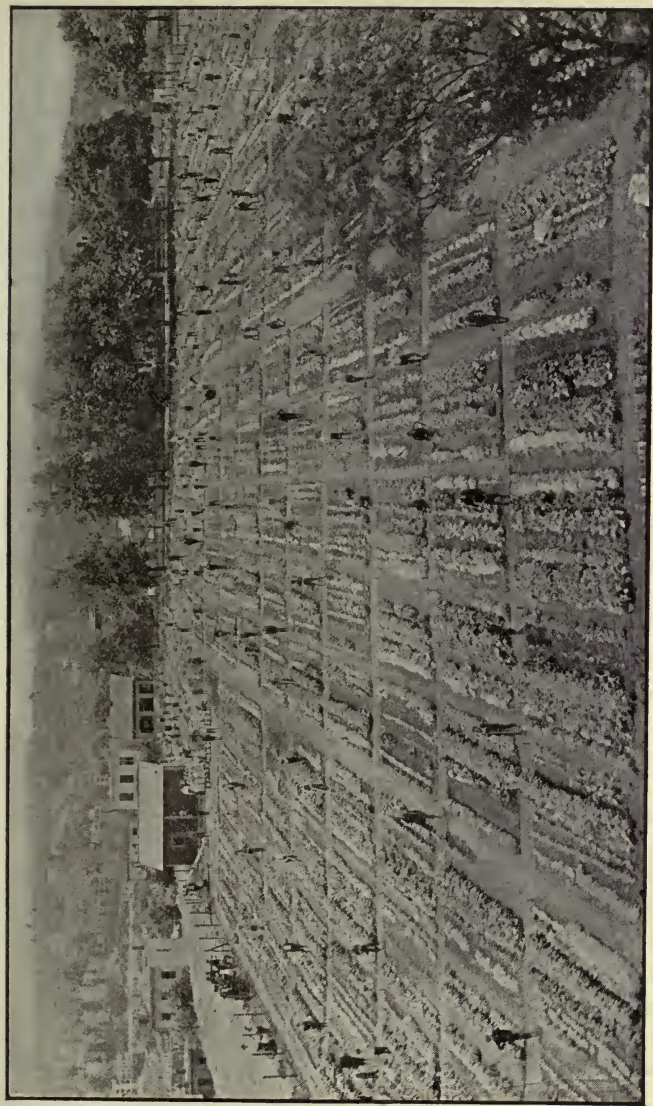
CHAPTER XXXV

SCHOOL GARDENS

376. The School is a place where many of our ideas and ideals are formed. It should be more than a place where we take short cuts to knowledge, that is, learning from teachers and books what others have found out by observation and investigation. Nature does not teach by words, pages or chapters. To understand nature's forces and how to control them, for our benefit, we must get close to her creatures.

377. The School Garden should be a place to learn what is true, beautiful and useful about plants, insects, soils, birds, sunshine and rain. We may do this by working with nature, by growing a small number of several kinds of plants and observing their needs as they grow from seed to fruitage. In outward appearance, school gardens do not differ from home gardens. All the common sorts of plants may be grown in a school garden, though we observe and study them more closely. Some plants must be cultivated one way, while others require different care. In a school garden we seek the explanation of the differences. If we grow a small number of plants and observe the progress of each separate plant, we shall learn a great deal about how to care for a large crop. (See Frontispiece.)

378. Laying Out a School Garden. When a piece of ground has been secured it should be cut up into a number of small gardens—one for each student. A



A garden school. One object of education is to train the mind to direct the hands to do useful things well.

diagram should be made showing all the walks and the location of each student's plot. Space should be left for walks between the gardens sufficient to allow access on all sides: The main walks may be five to eight feet wide, and the smaller walks only eighteen inches wide. A larger plot should be left for growing corn, pumpkins and other plants too large for the individual gardens. All students should take part in caring for the large plot. The laying out of the entire garden, and all questions about how it should be managed should be fully discussed by all students. Each student should make a plan and submit it to the teacher, who will select the best.

379. Individual Gardens. Every student—boy and girl—should have a small plot of ground on which they will begin work in the fall at the opening of school.

Each student should make a plan for his or her garden, covering the preparation of the ground, selecting the kinds of plants or seeds to be grown, and all other important features. If the teacher approves the plan, the work may be begun. If any changes are desired, the consent of the teacher should be secured before carrying them out. The students remain responsible for the success and appearance of their plots. Some gardens will be so fine that they will show the importance of care. No student should allow his or her garden to be pointed out as an example of what neglect will do.

380. Selecting Plants. In selecting plants for the garden, preference should be given to kinds that will mature during the school term. Some hardy sorts may be planted in the fall.

Many plants mature so quickly that two or more crops may be grown on the same land. The plan for the garden should show how and when the land will be

prepared, where each kind of plant will be in the garden, how and when each kind will be planted. Each student should strive to do well. Figs. 170 and 171.

381. The School Grounds should be made attractive by planting trees, shrubs, flowers and vines. Just as every one takes pride in the appearance of the home lot, so does the community feel a pride in keeping the school grounds in order. The school grounds should be kept in order by the pupils even during vacation.

Followed by tomatoes	Dwarf Nasturtium
	Radish
	Radish
	Radish
	Lettuce
	Lettuce
Followed by beans or millet	Beans
	Beans
	Beets
	Beets
	Beans
Followed by cowpeas	Turnips
	White Oats
	Red Oats
	Barley
	Wheat

Fig. 170. Plan of a garden with vegetable and field crops

Followed by tomatoes	Petunia
	Petunia
	Zinnia
	Zinnia
	Ageratum
	Nasturtium
Followed by turnips	Radish
	Radish
	Lettuce
	Lettuce
	Beets
Followed by turnips	Beets
	Beans
	Beans
	Beans
	Poppies
	Shirley Poppies Plant in Fall

Fig. 171. Plan of a garden with flowers and vegetables

CHAPTER XXXVI

FORESTRY

382. A Forest is a considerable piece of land covered with large trees. Forests are directly important to mankind as sources of fuel, lumber, heavy round timber, such as posts, piling, and telegraph poles; also, cooperage stock, tan bark, wood pulp for paper-making, rosin, cork and many other useful supplies. They are also important because of their good effect in regulating stream flow, preventing the erosion of the land and, probably, in modifying climate.

383. The Need of Forests was not fully recognized by the early settlers in timbered regions. The heavy timber was looked upon as an obstacle to rapid progress; but, in recent years, when railroads are at hand to haul the forest products wherever they may be needed, they are quite valuable. Before a piece of timbered land is destroyed, the probable value of the annual harvest of forest products should be carefully considered. America is now repeating the forestry experiences of European countries. The forests were first destroyed to make room for the fields, gardens and orchards, and, as the farming interest reduced the timbered areas, fuel and lumber supplies became more difficult to secure. Then the forest was looked upon as something of value that should not be destroyed. Where the natural covering of the hills and bottoms has been removed, the bad effects caused by the washing of the soil from the hills and the flooding of the valleys have been plainly seen.

384. Systematic Forestry teaches us to remove only the matured products, leaving the young timber to grow. France and many European countries have had to restore, though at great expense, the forest conditions to large areas that had been thoughtlessly destroyed. In many of the Old World countries no man is allowed to destroy a mature forest tree without permission of a forest official, and this is often given only when another is started to take its place. Such restrictions seem needlessly severe to us, but is it improbable that, some day, we may find some such restriction necessary for the public good?

385. The Exhaustion of Our Forest Resources is now going on at a rapid rate. Our forested areas are being rapidly reduced. Fig. 172 illustrates the present difference between the use of forest products and the rate of increase by growth. The eastern states have long since all but exhausted their natural forests. They once secured the needed supplies of lumber from the virgin forests of the north central states, but today those areas are almost exhausted and the large lumber supplies are now furnished by the northwestern and southern states. The citizens of many states have heretofore referred with pride to the great value of their annual crop of forest products; but the time has come in many states where the crop removed is greater than the crop that grows. Scientific forestry does not mean that the use of



Fig. 172. Excess of annual cut over annual forest growth.

forests should cease; but, rather, that in their use the needs of the future shall be considered in their relation to man and his various industries.

386. Conserving Our Forest Resources is a national need. In former times the lumberman cut everything. The young timber was needlessly destroyed. Now, however, they have realized the value of the small seedlings and saplings, and seek to protect them from forest fires and the grazing of stock. All the conditions that favor the growth of the young trees are carefully considered by the modern forester.

387. Our Forest Reserves. Our government, observing the great hardships resulting from an insufficient supply of forest products in the Old World, and how quickly the forests of the East and middle states have been reduced, has set aside large tracts of timbered regions in the western states as National Forest Reserves. These reserves form but a small part of our present forest resources; but, taken with the privately owned forests, are sufficient to supply our needs if properly used. Forestry plantings have been maintained in older countries for long periods and experience has shown that such plantings yield an annual revenue equal to four to eight dollars per acre.

388. The Forest Service of the United States Department of Agriculture, and the Forestry Commissioners provided for in many states, study the problems of forest management and issue bulletins of information for the instruction of all who have land suitable for timber-growing.

389. The Farm Wood-Lot. In many sections the waste lowland and the hill land may be planted to trees to supply fuel, poles and the many special timbers

needed on every farm. In many cases such lands have been made to return to the farm products equal in value to the returns of the regular field crops. The value of a wood-lot will depend much upon the care, nature of the soil, and the kinds of trees planted. Of course, it takes some years before the first harvest can be made; but this may be greatly shortened by planting thick and

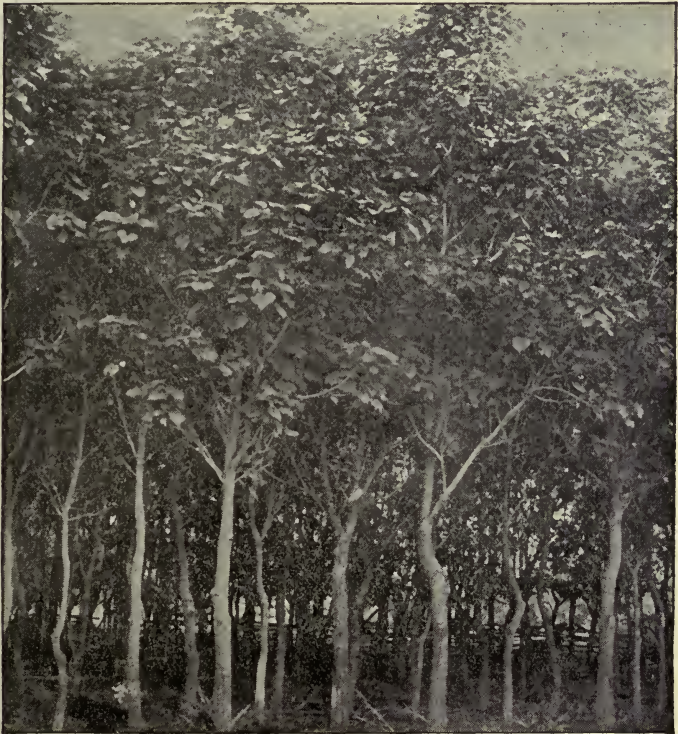


Fig. 173. A catalpa plantation. Every farm should have a wood-lot.
From Year Book, United States Department of Agriculture, 1899.

cutting out the less desirable forms as the growth thickens. Varieties for wood-lot planting should be selected to suit the locality. Hardy catalpa, black locust, black walnut, honey locust, Bois d'Arc, or Osage orange, mulberries, and many other sorts, have proven to be well suited to many sections of the South and West. Not every wood-lot has turned out a success; but a larger number have. Many failures are due to neglect or to the use of species unsuited to the conditions.

389a. A farmer planted a large acreage of bottom land to hardy catalpas, in rows six feet apart and four feet apart in the row. At the end of ten years he found the books showed the following items: Cost of rent on land for ten years, seedlings, planting, cultivating, trimming, marketing, etc., \$56. Value of stakes and small posts secured, early thinning, \$63. Stock on hand: 678 posts, first class, 10 cents each; 712 posts, second class, 7 cents each; 616 posts, third class, 4 cents each. What was the approximate value per acre per year of the crop?

390. Windbreaks. In open regions, windbreaks, formed by growing shrubs and trees, have been found to be quite beneficial because of the protection they give to growing crops and orchards, or to stock. Windbreaks reduce the evaporation from the soil and from the plants themselves. They often prevent the drifting of the soil in open, sandy regions. They also protect stock from cold winds in winter and hot winds in summer. In regions that most need windbreaks, it is most difficult to get the trees to grow. The plan that has proven most satisfactory is to make plantings of arborvitæ, locusts, Osage orange, red cedar, blackberries, green ash, or other species in wide rows and cultivate the trees until they become thoroughly established. It is not advisable however, to use cedars in windbreaks for apple orchards, because they aid in the spread of the apple rust.

CHAPTER XXXVII

FARM MACHINERY

By PROF. J. B. DAVIDSON, Professor of Agricultural Engineering,
Iowa State College

391. Progress in Agriculture owes much to the introduction of machine methods for doing hand labor. When the savage began to plant seeds with a sharp stick instead of depending on wild nature, the idea was certainly a progressive one. When he learned that destroying the weeds that came up with those seeds would add to the quantity and the certainty of the harvest, he ceased to be a savage. Still again, when he learned to prepare the ground and cultivate his crops, civilization was well established. "Civilization begins and ends with the plow," and yet the plow remained a crude wooden tool until within comparatively recent times.

392. Tillage Tools were not noticeably improved until chemists and botanists began to study the soil and formed a theory about the relation of the soil to the plant. Machines are not invented until the need for them is recognized. The ideas about the relation of the plant to the soil given in modern books would have been wondrous strange to our great-grandparents. McMaster* tells us that "The Massachusetts farmer who witnessed the Revolution, plowed his land with a wooden bull-plow, sowed his grain broadcast, and, when it was ripe, cut it with a scythe and thrashed it out on his barn floor with a flail." These implements were

*History of the People of the United States

similar to the ones used by the Egyptians three thousand years before. It is worthy of note that many of the greatest of the early Americans were interested in the development of the plow, the fundamental implement of tillage. Thomas Jefferson and Daniel Webster planned plows and had them constructed, which were improvements over preceding types. In 1797, Charles Newbold introduced the iron plow, but it is recorded that the farmers of that time refused to use it, claiming that so much iron drawn through the soil poisoned the



Fig. 174. Daniel Webster's famous plow had a beam 9 feet long.

land and increased the growth of weeds. This latter superstition delayed the general acceptance of improved plows for many years. The use of iron and steel plows did not become general until about 1830. Many improvements were made in the construction and form of the points and mold-boards, adapting them to various kinds of soils. The modern plow is familiar to all. The recent types of sulky plows enable the plowman to ride in a comfortable seat, and, when properly adjusted, so that the pressure due to the raising and turning of the furrow slice is reduced, have no heavier draft than the walking plow. The single-shovel cultivator has given way to the double-shovel implement, and this, in turn, to the straddle-row cultivator, and, in many sections, the two- and three-row cultivators are finding favor.

393. Harvesting Machinery. Perhaps no line of development has assisted agriculture so much as machine harvesting. The grass hook and the scythe were long in use. When a Scotchman put fingers to the scythe, forming the cradle, it was heralded as a great invention because it enabled one man to do the work of several equipped with the older implements. Obed Hussey and Cyrus H. McCormick* stand out prominently in the development of the reaper, which was later improved by many others, among whom Palmer, Williams, Marsh Brothers, Spaulding and Appleby should be mentioned, leading up to the self-binder in 1878. It appears marvelous to find that there has taken place within sixty years—within the life of a single man—the universal introduction of machines which are so efficient and still require the guidance of but one man to do the work of many.

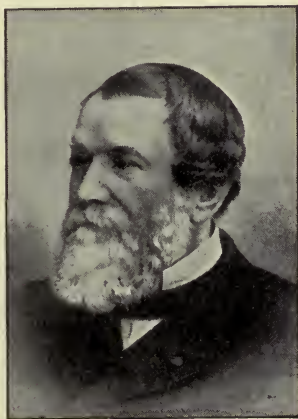


Fig. 175. C. H. McCormick.

394. Farm Machinery. The general introduction of specialized farm machines,—implements too complex

*Cyrus H. McCormick was born in Rockbridge county, Virginia, in 1809. His father had constructed a reaping machine, though his efforts, like those of many others along the same line, were not successful. Young Cyrus had watched his father's experiments and cherished the thought that some day he might solve the difficult problem. He abandoned the principles that had formed the underlying features of his father's machine. The elder McCormick did not approve of the young man's plans, but he put no obstacles in his way, and offered him the facilities of his little blacksmith shop to build his first machine. Young McCormick completed his first reaper in time to give it a trial in the harvest of 1831, and it worked successfully that year.

to be called tools,—has made the modern farmer a mechanic. Modern haying implements, consisting of mowers, rakes, hay-loaders, stackers and presses, have greatly reduced the hand work in hay-making. It has been estimated that the farmer of 1850 spent eleven hours in cutting and storing a ton of hay, while, under modern methods, the time has been reduced to one hour and thirty-nine minutes. There are machines for every

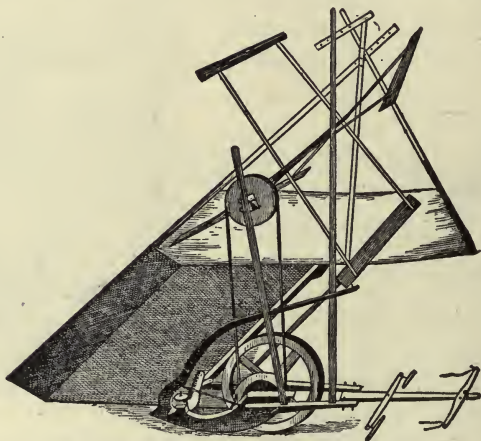


Fig. 176. McCormick reaping machine, 1834.

class of farm work: Threshing-machines for threshing grain; shellers, for shelling corn from the cob; huskers and shredders, for removing the ears from the corn-stalk and converting the latter into palatable food for farm animals, and many others. This is true to such an extent that large farms have nearly as much invested in machinery as some factories. Many forms of machinery used on the farm require considerable power. Wind-mills, gasoline engines, and even steam-engines, are not

infrequently in regular use for pumping water, grinding grain, separating milk and other special operations. These motors increase the capacity of the farm worker by enabling him to use and direct more power, resulting in more economical production. Fig. 177.

395. Power Versus Hand Labor. The change from hand tools to implements and special machinery has lead to the use of more power for each worker, and the



Fig. 177. A suggestion for the use of power on the farm. From an agricultural implement catalogue.

amount is governed somewhat by the ability of the worker. Man, when working alone, is able to develop only about one-eighth horse-power. When he uses one horse, his capacity to work is increased eightfold, and if two horses are used, sixteenfold. The American farmer is not content to let his brain drive a one-horse power when two, three or four may be used to advantage. This demand for more power has stimulated the breeding of larger horses for draft purposes.

396. Care of Machinery. The operation of many

forms of farm machinery often taxes the mechanical skill of the average worker. Much loss results from the neglect to repair agricultural machines promptly and systematically. Many machines are discarded which would be almost as good as new if the broken parts were replaced. Costly agricultural machines should be kept under shelter when not in actual use, to lengthen their period of usefulness.

397. The Influence of Agricultural Machinery on the quantity and quality of farm productions has brought many changes. The year 1850 has been mentioned as marking the transition from the use of implements for hand-production to those for machine-production. The increase in production per farm worker under modern methods is most marked. The Roman farmer in the time of Columella spent four and six-tenths days in growing a bushel of wheat. It is stated in the Thirteenth Annual Report of the United States Department of Labor that the American farmer spent three hours in 1830, under hand methods, in producing a bushel of wheat, at a cost of 17.7 cents, while now the same result is secured in nine minutes at a cost of 3.5 cents. In 1800, 97 per cent of our people were living on farms, or in small towns, depending upon agriculture for food; yet, with all this army of workers, the country raised only five and five-tenths bushels of wheat per person. In 1900, while approximately only one-third of the population lived on farms, the production of wheat was ten bushels per capita, one-half of which was in excess of our needs.

398. Other Changes in Farm Conditions have been made, at least in part, as a result of the change from hand methods to machine methods of production. An

old method of threshing grain was by the treading of animals, but bread made from wheat threshed in this manner would not be salable today. Women are no longer required to do heavy field work as they did at one time. The working day has fewer hours and the wages of the farm-worker has increased many fold. "All intelligent expert observation," says Dodge, "declares it beneficial. It has relieved the laborer of much drudgery; made his work lighter and his hours of service shorter; stimulated his mental faculties; given equilibrium of effort to mind and body; made the laborer a more efficient worker, a broader man and a better citizen."



Fig. 178. The modern harvester cuts, bundles, binds and deposits in piles ready for shocking.

CHAPTER XXXVIII

PUBLIC HIGHWAYS*

399. National Roads. In 1806, Congress authorized the construction of a national turnpike, from Cumberland, Md., to St. Louis, Mo., and continued to make appropriations until 1838. This road still exists and many sections of it are now in good condition. Most of the national appropriations for public roads were primarily for military roads, but the federal government has made no appropriations for road building since the beginning of the Civil war. Since 1892, Congress has provided for the "Office of Public Road Enquiry," for the purpose of experimenting on problems in road construction and studying the problems of road administration and maintenance.

400. Building and Maintaining Public Highways. Most of the states still have their roads in charge of county officers or other persons who, while generally competent in ordinary business undertakings, are not students of the technical problems of road construction or maintenance. In nearly every foreign country, road building and road maintenance is in charge of expert road engineers. In recent years, several states have established the office of "State Highway Commissioner," and provided for the state, county and precinct to share the expense of preparing or building roads. This is known as the "state-aid plan."

401. The Need of Public Highways. Good highways

* Acknowledgments are due Mr. T. W. Larkin for generous assistance in the preparation of this chapter.

ought to be maintained by and for all the people. They make travel to and between cities, towns, neighborhoods, schools and churches easy, quick and economical. They not only save valuable time, reduce the cost and increase the comforts of overland travel, but the schools and churches are more accessible,—hence more useful and effective. The improvement of public highways has for years been strongly advocated by the brightest minds of the country, and these advocates, after pointing out the importance of such improvement to the material advancement of the agricultural and commercial interests, dwell upon the benefits to the social fabric, which means so much to public progress. It is urged that improved roads greatly lessen the cost of transporting the products of the farm to the market, thus increasing the earning capacity of the producer and likewise increasing the value of the lands having access to such roads. It has been said that wherever the best roads are found there are also found the best homes and the greatest perfection of living conditions on the farm. Good roads are very essential to the greatest degree of comfort in rural living. Good roads make possible the profitable employment of teams at times when field work cannot be done, thus reducing the amount of idle time, and enable the marketing of produce when market conditions are most favorable. It is also notable that, in communities where the highways have been improved, social conditions are improved by reason of the ease of neighborhood visits and attendance upon social events.

402. When Shall Public Roads Be Built. Good common highways do not exist naturally. They must be made and kept in repair. If the expense of hauling the

products of the farms and mills back and forth is greater on bad roads than on good roads, we might designate this difference as the "bad-roads tax." If the bad-roads tax on a community is enough to build and maintain good roads, the wisdom of the building is at once apparent. Statistics compiled by students of the problem of public highways say that the heaviest road tax is paid by the farmer who is compelled to haul his products over a neglected road.



Fig. 179. If fifty tons of freight are hauled over such a road daily, what is the cost to the community for a year?

402a. Problem. Farmer Jones has a farm of 160 acres, six miles from the railroad. He raises corn, cotton and oats as money crops. He has 40 acres in corn, averaging 40 bushels per acre—1,600 bushels—115,200 pounds—576 tons. His roads are such that in good weather he can haul one ton and make one trip a day. If a driver and team be valued at \$2.50 per day, how much does it cost per ton to deliver his corn to market? How much per ton per mile? (41 cents) Would this latter figure be approximately true whether

the hauling trip were two or six miles? How much would it cost to haul the 1,600 bushels to market? Figure cost per bushel; cost per acre; approximate tax on the entire farm.

402b. Problem. The road traveled by Farmer Jones was graded, ditched and drained, bridges put in at bad places, hills cut down to reduce the grade, and so improved that the same team could haul 3,000 pounds and make two trips per day. Make similar calculations as above. Determine the approximate "bad-roads tax" on Farmer Jones.



Fig. 180. If fifty tons are hauled over such a road daily, what is the cost to the community for a year?—A demonstration road being built by Office of Road Inquiry, United States Department of Agriculture.

403. Cost of Overland Transportation. In some investigations made by the United States Department of Agriculture, it was found that the average cost of hauling twenty-three different farm products to market represented a sum equal to 1.4 per cent of the value for cotton, 2.7 per cent for wool, 4.3 per cent for peanuts, 5.2 per cent for rice, 5.3 per cent for flax seed, 7.2 per cent for wheat, 7.7 per cent for oats, and 9.6 for corn.

The general average cost on all crops was found to be 5.22 per cent of the value.

The cost per ton per mile figured on actual loads and cost of hauling averaged 25 cents divided as follows: 15 cents for flax seed; 16 cents for barley; 19 cents for wheat, rye, hops, hay and corn; 22 cents for wool and potatoes; 27 cents for cotton and cotton seed; 25 cents for apples and live hogs; 30 to 31 cents for peanuts and fresh vegetables. These figures were based on reports from all parts of the United States, and of course are merely averages for all sorts of roads. In some cases the cost was greater and in others less than the figures given.

The difference in cost of hauling over good roads and poor roads is shown by the following figures of cost of hauling per ton per mile, based on European investigations:

	Per ton mile
On broken stone roads, dry and in good condition.....	8.0 cents
On broken stone roads, ordinary condition.....	11.9 cents
On earth roads containing ruts and mud.....	39.0 cents
On sandy roads when wet.....	32.6 cents
On sandy roads when dry.....	64.0 cents

404. Cost of Steam Transportation. The average freight rate by rail per ton mile for 1906 was \$0.00766 per ton mile. Average cost by ocean freight New York to Liverpool, a distance of 3,100 miles, was in 1906 \$1.006 per ton on wheat, or \$0.0003 per ton mile. The great significance of these figures is shown when compared with the following:

	Per ton mile
Average rate on country roads.....	25 cents
Average rate for corn on country roads.....	19 cents
Average rate for corn on hard roads.....	10 cents

405. How the Road Surface Affects the Draft. The firmness and smoothness of the road-bed affects the draft required to move a load very materially. The

following figures based on actual tests will enable one to see at a glance the great value of good road-beds. If a horse has a load that he can just draw on a level road of iron rails, it would require the power of one and one-half horses to draw the same load on hard asphalt, three and one-half on smooth block pavement, seven on cobble-stone pavement, thirteen on bedded cobble stone, twenty on an ordinary earth road, and forty on a sandy road.

The following table shows the results of tests made with an ordinary wagon equipped with an automatic scale or dynamometer, used to measure the traction, or pull, in pounds:

Character of surface	Wide tires, 4 inches Load weight, 4,345 lbs.		Narrow tires, 1½ inches Load weight, 4,235 lbs.	
	Starting Lbs.	Average pull Lbs.	Starting Lbs.	Aver. pull Lbs.
On block pavement..	350	100	300	75
Hard sandy roads....	700	275	725	300
Good level gravel roads.....	600	175	650	175
Soft muddy roads....	800	550	900	500
Deep muddy roads...	1,050	550		
On muddy dirt roads with ruts made by narrow tires.....		900-1,600		

Character of surface	Wide tires, 3 inches Load weight, 4,590 lbs.		Narrow tires, 1½ inches Load weight, 4,590 lbs.	
	Starting Lbs.	Average pull Lbs.	Starting Lbs.	Aver. pull Lbs.
Across fields cutting sod 1½ inches.....	1,100	550	1,250	650
Good hard roads.....	700	350	850	350
On pavement.....		125		

Other results have shown that to draw a ton on hard, smooth macadam road required 45 pounds pull, on hard rolled gravel road 75 pounds, and on earth roads 224 pounds. It will thus be seen that a good road-bed enables a horse to draw from two to five times as much on level roads as on rough roads.

406. How the Grade Affects the Draft. In improving roads, it is very important that the steep hills be avoided by cutting down at top and filling in at bottom, or by putting in bridges. This work is often very expensive and, wherever possible in laying out a road, the expert engineer will throw his line along the side and around the end of steep hills, even though the distance be somewhat greater, for the increased travel is more than offset by the increased hauling capacity. It is almost impossible to avoid a considerable grade in constructing a road over a hill. It often happens that a road may be thrown around a hill instead of over it, without increasing the distance to be traveled. This may be illustrated by cutting a well-formed apple in halves. With a tape-line find the exact center on the side and between the ends. Then measure the distance over the piece of apple and the distance around either end to the exact center of the opposite side, and it will often be found about the same.

It has been found that when a horse can pull a 1,000-pound load on a level road he can draw only 900 pounds up a 1 per cent grade, 800 pounds up a 2 per cent grade, 400 pounds up a 5 per cent grade, and only 250 pounds up a 10 per cent grade. It might be interesting to determine the grade of some hills in the school district. A spirit-level and a tape-line will be needed.

A horse may pull only one-fourth as much on a 10 per cent grade as might be pulled on a level road. How-

ever, a horse may exert twice his average pulling strength for a few minutes. In the case of a very long hill, it might in some cases be better to make a number of steeper but shorter pulls than to make one long gradual pull. Thus we see that grades greatly decrease the hauling capacity, and, inasmuch as whatever decreases the hauling capacity correspondingly decreases earning capacity, the importance of reducing grades in road improvement is easily understood.

407. Effect of Width of Tire on Draft. It is important to know the effect of the width of the tire on the amount of draft required to move a load. The results given in the table (§ 405) are fairly representative. These results and many others indicate that there is no advantage in wide tires on pavements and very hard roads, but for ordinary country hauling the wide tire offers several advantages. Narrow tires are very destructive to road surfaces, but wide tires roll and harden the surface like a roller.

408. Good Road Essentials. A road should have a smooth, hard surface and a reasonably level grade, and it should have such a foundation that it will maintain its smooth surface in dry as well as wet weather, that is, its essential qualities should be permanent. In building roads, therefore, they should be given such form and construction as will maintain these qualities under constant use in varying weather conditions. Drainage is the all-important problem encountered by the road engineer. The road must be so laid out and constructed as to shed water as quickly as possible, to prevent damage, to surface and foundation. (Fig. 181.) The surface of the road-bed should be slightly elevated in the middle, so that the rain-water will run immediately to the side ditches before it has time to penetrate into the foundation.

Not only this, but side drains should be large enough to carry off all water without washing, and graded to prevent the formation of pools on the sides. The water-table should be kept well below the surface of the road.

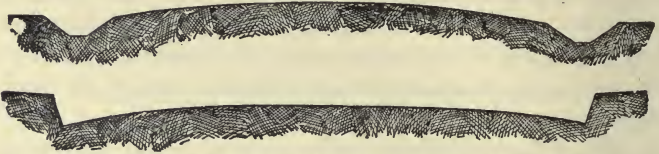


Fig. 181. Cross sections of two good forms for earth roads. The lower section can be made with a road machine, and both sections can be maintained with a split-log drag so that water will run off easily and quickly.



Fig. 182. Cross section of a road showing the result of improper construction and drainage. Note that the center of the road has become the lowest part and that water may collect on the surface, making the road practically impassable.



Fig. 183. Cross section of road, showing clay cover on "deep" sand subsoil



Fig. 184. Cross section of Macadam road, showing a compact foundation of earth supporting a solid and durable stone surface.



Fig. 185. Transverse section of Telford road with Macadam surface.

Suitable culverts should be provided to dispose of storm water. These should have sufficient fall from the upper to the lower side to wash out all sediment.

409. Surfaced Roads. Different kinds of material are used in surfacing roads. In sections where suitable gravel

is found, some splendid roads are found surfaced with this material. In communities near the coast, shells have been used for road surfacing with good effect. But probably the most popular and generally employed material is broken stone. Roads thus surfaced are said to be macadamized, being so called for the reason that John Loudon Macadam, a Scotch engineer, was the first to advocate and employ this plan of road building. The old Roman roads, which figure in history, were surfaced with stone, in some instances the stone surface being several feet thick; but Macadam worked upon the theory that a smaller amount of stone properly consolidated would serve the same purpose with less expense. Time proved his theory correct, and Macadam is quoted in almost every work on road construction. Another Scottish engineer who advanced many splendid ideas in road building and also won fame as a road builder during the days of Macadam, was Thomas Telford. The Telford roads are built with the lower layer of broad, flat stones set on edge by hand. This is considered by many road builders to be a useless expense except when the foundation is soft. In the Mississippi delta, where the roads are over sedimentary clays, commonly known as "gumbe," or "buckshot," the burnt-clay method of surfacing has been successful.

410. Earth Roads. The building of modern highways is being urged throughout the country as their importance becomes realized, especially with the increase of overland traffic and the ever-increasing demand for better transportation facilities from the farm to market, and growing tendencies toward better living conditions in the rural districts. For many years to come, the earth road mileage will probably be by far greater than that of surfaced road; hence the care of earth roads

presents a problem that should engage the thought of every one. Wherever it is not possible or practicable to pave or surface the roads, they should as least be properly graded, and so laid out as to reduce grades to

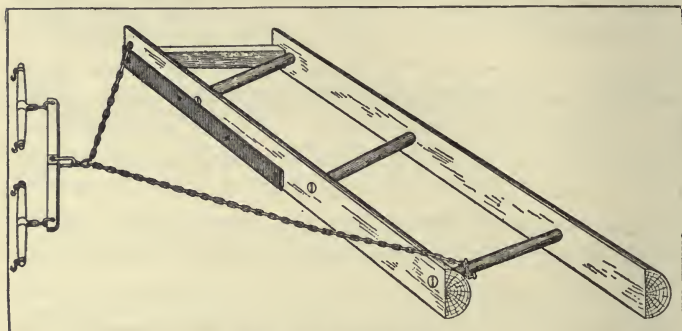


Fig. 186. A split-log drag

the minimum and provide the best possible drainage. A well-drained road will not cut into deep ruts, which are so annoying on neglected earth roads.

411. The Split-log Drag. The split-log drag is a simple device that can be used effectively for the immediate betterment of earth roads. It has been enthusiastically advocated throughout the country during the past few years and many of them are being effectively used. The drag is usually made and operated by progressive farmers, who after each rain, if the conditions of the road requires it, drag the road from their own gate to the gate of the neighbor, who is expected to do likewise. Wherever this plan has become well established, the roads have been greatly improved. The drag is most effective if used when the ground is just beginning to dry; that is, moist but not sticky or puddle. The drag is so simple in construction and operation that any school-boy can do it all with ease.

The most important part of road dragging is using the road drag promptly and persistently. Drive up one side of the road and back on the other, covering one rut in each case. By riding on the outer or ditch end of the drag the loose dirt picked up near the ditch line will be gently moved along by the drag, filling ruts and holes and leaving the surplus in the center of the road to be travel-packed, thus gradually giving the road oval formation.

The driver will soon learn that by moving about on the drag a greater or less amount of dirt can be moved, and that it can be dumped as desired. There is a ridge for every rut in the road; the drag cuts down the ridges and fills the ruts, thus preventing water from standing in these holes and soaking into the roadway. Keep the ditches clear, keep the roadway smoothed down with the drag so that the water may move quickly, and any earth road can be made good for travel at all seasons.



Fig. 187. A split-log drag, properly used, means a smooth, serviceable earth road free from ruts, mud holes and weeds. Also a reduction of mud in wet weather and dust in dry weather,—all at small cost. From photo specially furnished by Office of Public Road Investigations, United States Department of Agriculture.

CHAPTER XXXIX

SELECTION OF FARM CROPS

412. Now that we have learned something of the general principles of plant growth, we may more profitably study the special requirements and uses of the most important field, orchard and garden crops. We have learned something about how plants grow. The Average yields of staple crops in all countries is much below the possible yields. Often only a fence separates a field averaging only 20 bushels of corn to the acre from one averaging 40 bushels. This average yield of corn in the United States is less than 25 bushels per acre, yet most farmers recognize that it is within their power to make their yields exceed this average.

413. The Four Essentials. We have learned that all green plants require four important conditions for full success; i.e., sun light, air, constant supply of water, and certain mineral substances found in the soil. The control of the last two constitute the foundation of cultivation and is the first problem in successful crop raising. Cultivation includes more than simply plowing the soil. It is making a favorable environment by any means. The difference between the 20 and the 40 bushel crop can be accounted for largely by the way these conditions are controlled.

414. The Second Most Important Problem of the farmer is to learn to select seed from the better producing plants, from which to grow succeeding crops. It is clear that we would profit by a better seed, but it is often a



A field of strawberries looks good close to home,—and brings some money at harvest time. Hill system in foreground (See Fig. 225) and matted rows beyond.



Good live stock and good pastures should be features of most farms. See ¶258.

task for our intelligence to determine which, out of a dozen or more plants, will furnish seed that will produce a better crop. If a special variety has better quality in its fruit, fiber, or stalk, or makes larger yields than others, it is usually because someone has recognized these qualities and perpetuated them by constant selection. (§ 204).

415. Selection of Crops to Suit Climate and Soil.

It has been found that climatic influences, such as air moisture, soil moisture, rainfall, temperature, and winds, are very important conditions determining what crops are profitable or even what varieties of a particular crop are most successful in certain sections. On going into a new section of country, it will usually be best to follow the practice of the older residents and to experiment with introduced forms only on a small scale, until their adaptability can be better determined. As a general rule, those varieties are best that have longest been grown and most carefully selected in the climatic region in which they are to



Fig. 188. Select varieties suited to the climate in which they are to grow. On left Dakota White Corn in North Dakota; On right Ferguson's Yellow Dent Corn in Oklahoma.

be used. (§ 213). The varieties of cultivated crops brought to the West from the East by the early pioneers, are seldom in use there at present. They have been replaced by varieties that have been developed in the West. We have here an illustration of a general rule that has few exceptions.

416. Mixed Farming. It is rarely advisable for a farm to grow just one kind of crop. For example, a large corn crop would require more labor to cultivate at one season than one man could supply, and later leave him without employment. Farmers, therefore, usually find it more profitable to grow several kinds of crops. Other reasons favoring mixed farming were given in chapter XV. Can you name them? (See § 146).

417. Mixed Farming and Crop Failures. If a farm producing only one crop should be affected by adverse weather conditions, low market values, etc., the farmer's small returns for that season might seriously impair his working capital. If he has several kinds of crops maturing at different seasons of the year, it would be unusual if some of them should not make a fair return. Mixed farming, therefore, tends to average the hazards which farmers must take against unforeseen weather conditions, and tends to give stability to total annual revenues.

418. The Size of the Farm will depend much upon the selection of crops to be produced. In a general way it is advisable to have the farm large enough to justify a reasonable investment in labor saving machinery, draft animals, and other conveniences that place a premium upon intelligence, rather than mere physical strength. (§ 394). Experience has shown that farms growing general field crops and stock yield a more profitable return when large enough to give employment to two or more

men. There are many operations that can be more profitably performed by two or more persons than by one. The actual area of the farm will depend very much upon the requirements of the crops produced. For the common field crops, one man may care for from 40 to 125 acres, with only a moderate amount of extra labor at certain seasons. In vegetables or fruits a few acres may afford employment for a number of men.

419. Intensive and Extensive Farming. By intensive farming we mean that extra efforts and outlay are made to increase the acre yields. Special efforts are made to have the environment correspond closely to the requirements of the plants. Special preparation of the soil, irrigation, liberal use of fertilizers, frequent cultivation and specializing in just a few kinds of crops of high market values, are features of intensive farming. Examples are, onions, celery, and greenhouse plants. Crops where quality more than quantity determine the acre-values are usually more profitable when grown on an intensive basis. Bulky field crops of comparatively low value, while giving increased yields, do not usually make correspondingly profitable returns when grown on an intensive basis.

The pastoral farming of the pioneers represented an extreme type of extensive farming. The other extreme is found in the market gardens, greenhouses, and orchards of the present day where a single acre may be made to produce several hundred, or even several thousand dollars' worth of products.

CHAPTER XL

PASTURE CROPS

420. When crops are harvested by grazing animals they are called pasture crops. If cut green and fed in this condition, soiling crops (§ 346) but if allowed to dry and cure they are called hay crops. When harvested green, cut up and stored in silos it is called silage. (§ 355).

421. The Value of Pasture Crops is generally underestimated because they are not converted directly into money. (§ 258). In the bluegrass region cattle get about half of their living on good pastures by grazing and it takes from 2 to 8 acres to furnish pasture feed for a three-year-old steer. Pastures are useful in ways which cannot be easily measured in a money equivalent. Work animals remain in much better condition if allowed to run in pastures. And again, dairy and other cattle that live out of doors upon pastures are healthier than when housed or closely penned. The best returns from pastures are secured in the dairy sections of England, the Jersey Islands, Holland, and Denmark, where more than half of the cultivatable lands are in permanent pastures. There a cow is kept on two or three acres, one-half of which is pasture. In some of these countries a large family will be prosperous on a 60 acre farm and pay a rental of seven or eight dollars per acre.

422. Plants Suited to Pastures. In grazing, the upper parts of the stems and leaves are removed or tramped upon and disturbed by the animals. Good pasture plants have habits of growth such that they are not permanently

damaged by a limited amount of this kind of treatment. The grasses are well suited to grazing because their stems and leaves grow in length largely from near their bases. They also have a habit of stooling or suckering, forming many stems, especially so if the older ones are grazed off. They form a turf out of the upper layer of soil that largely protects the roots from the tread of the grazing animals. Bluegrass, Bermuda grass, mesquit grass, and many



Fig. 189. Plowing Hungarian Brome grass sod five years after seeding.
Kansas Agricultural College.

others on the western ranges have perennial roots, and form stooling, suckering stems, or rhizomes, and grow throughout the warm seasons.

423. Valuable Pasture Plants in any country are few in number. The principal grasses are bluegrass in the North and Bermuda in the South. Besides these two, awnless or Hungarian brome grass, timothy, redtop, and orchard grass are extensively used in the North; and redtop, Johnson, Guinea, Rhodes, rescue and Para grasses in some sections of the South. A good pasture grass

should produce an abundance of good seed and in such a way that they may be easily harvested. Our best pasture grasses, however, do not meet these requirements, but we employ them because they produce an abundance of basal leafage from persistent rootstocks.

424. To Keep a Stand on pastures composed of annual plants it is necessary to allow the plants to seed naturally, or to re-seed the land each year. For pastures composed of perennial plants that multiply by the growth of rootstocks, or rooting stems, it is necessary to allow sufficient growth to insure that food be stored to encourage the growth of these parts. Just the opposite procedure is followed in trying to starve out weeds. (§ 62).

425. Management of Pastures. The amount of feed produced by pasture plants is determined by the same general conditions that control the growth of cultivated plants. For large returns they must have a rich soil, plenty of water, and develop large leaf surface. The tendency in pastures is for the surface of the soil to become hard, due to the trampling of stock and the binding effect of the roots. Harrowings and top dressings with manures are often very beneficial. We have previously learned that plant food is manufactured in the 'green leaves. The amount of leaf surface exposed to sunlight is a measure of the capacity of the plant to manufacture plant substance. (See § 46-48; also 149 and 152).

426. Close Grazing. Young pasture plants, or plants grazed closely through the winter should not be grazed when just coming out in the early spring. It greatly retards the rapidity of their later growth. Pastures that are grazed closely do not form vigorous plants and therefore have weak roots and soft turf. Grass pastures having leaves four to six inches long will have more than treble

the producing power of those with leaves only two or three inches long. It is more profitable to feed animals than to so overstock the pastures that their growth is retarded. A better practice is to divide single large pastures into two or more, and graze one at a time.



Fig. 190. Pasture on left grazed so closely that the value of the crop is greatly reduced. On right not grazed enough to secure full advantage of the crop.

Courtesy Dr. David Griffith, United States Department of Agriculture.

427. Weeds in Pastures. Pasture lands are sometimes infested with weeds,—plants that stock will not eat. Annual weeds may often be destroyed or reduced by mowing while they are in flower, or before their seeds are ripe. Perennial weeds are more difficult to eradicate and the habits of each species must be studied. A few sheep and goats are often desirable in pastures because they prefer the leaves of weeds and bushes to the regular pasture plants, and thus turn the objectionable weeds into a profit while destroying them. (¶ 306).

CHAPTER XLI

LEGUMES

BY PROF. A. D. McNAIR, U. S. Department of Agriculture.

428. Importance of Legumes. We have already learned (§ 125) of the association of legumes and certain bacteria, that have the power of converting the free nitrogen of the atmosphere into compounds usable by their host plants. While the bacteria in the nodules on the roots in some way gather the free nitrogen of the air, yet it is not retained by them, but enriches the entire host plant (§ 124-130). For this reason they are called "nitrogen gatherers." When properly used, legumes are true soil builders.

429. Formation of Tubercles and the Accumulation of Nitrogen. All species of legumes form tubercles on their roots, when the proper bacillus is present. In soils rich in soluble nitrates the number of tubercles is often small, while in soils deficient in nitrates, the number is usually greater. Legumes that have tubercles on their roots grow more vigorously and are richer in nitrogen than those that do not have tubercles. From this it is inferred that leguminous plants acquire the free nitrogen of the air when compelled to do so, but when the soil contains an abundance of nitrates, they utilize a larger proportion of the nitrogen salts in the soil.

430. Soils and Fertilizers for Legumes. Alfalfa, the true clovers, beans, peanuts, and field peas are benefited by free lime and rarely thrive in acid soils. (See tests in § 141). Cowpeas do not require so much free lime, and the same is probably true of soy beans and lespedeza.

Phosphorous, potash, wood ashes and manure are beneficial to legumes. Nitrogenous fertilizers are rarely applied to soils cropped in legumes, though in planting them it is sometimes desirable to give a light dressing of some fertilizer containing nitrogen to give the young plants a good start.

431. Clovers. Clover is a general term applied to a number of legumes. Red clover, and its more vigorous variety, mammoth clover, are largely grown in the United states north of a line from Oregon to Alabama. White clover is a hardy, spreading perennial used largely in pastures in regions north of the Cotton Belt, yet grows well on lowlands in humid regions in the South. Owing to its winter-growing habit, it is particularly desirable in combination with Bermuda grass in the South, to furnish an almost continuous pasture. Crimson clover is a winter annual not much used for hay, but highly esteemed in the South Atlantic States as a winter cover crop for orchards and a soil renovating crop in rotations. The seed are sown in the fall and the crop plowed under in the spring in time to plant other crops.

432. Alfalfa or Lucerne is not truly a clover, but it may be said to be the clover of the West, and in the mild climates of all countries where soils are suitable. It is well suited to both moist and dry climates, and responds freely to irrigation. It has deep growing roots and withstands dry weather as well, or better than any other forage plant. (Fig. 191). Alfalfa needs a porous subsoil, not so much because of inability of the roots to penetrate stiff soils, but because an excess of water in the surface soil is highly injurious.

433. Alfalfa is a perennial, forming a "crown," with many stems as it grows older and is mowed off. The

seed are small and produce delicate seedlings which may easily be destroyed by dry weather, extreme cold, or weeds, though when once established, the plants are quite resistant to all. It is never advisable to attempt seeding

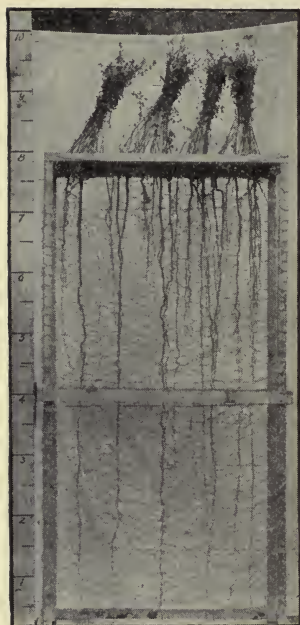


Fig. 191. Alfalfa plants showing crown of stems and deep feeding root.

Kansas Agricultural College.

alfalfa on foul land. Alfalfa seed retain their vitality for years. The seed bed should be mellow and well settled before the seed are sown. In most sections, sowing seed in late summer or early fall is preferred to spring seeding. It is usual to plant about 10 to 20 pounds of seed per acre.

434. Southern Clovers.

There are two classes of clovers common in the humid regions of the South. Lespedeza or Japan clover is a summer growing species, and is an important hay crop in portions of Arkansas, Louisiana, and Mississippi, and for pasture in other sections. The Burr clovers are low winter growing legumes originally from southern Europe, now widely

naturalized in the South and in California. They are highly valued for grazing and as soil improving crops.

435. Peanut. The peanut is a low-growing tropical annual requiring 100 to 150 days of warm weather to mature a crop. Sandy soils are preferable because the nuts are not stained as they are on heavy clay soils.

The Virginia variety is usually shelled by hand before planting, but the Spanish variety is often planted in the pod. The average yield is about 25 bushels of nuts and a ton of hay per acre. The old notion that the yellow flowers should be covered with earth is a mistake. After pollination takes place the showy yellow male flower fades away, while the small female flower grows downward by the extension of the flower stem until the sharp pointed "pegs" or ovaries are thrust into the ground where the pod develops. It is well to keep the soil quite mellow until the pegs or ovaries begin to reach the ground.

436. Cowpeas, in

Europe are more properly called "China Beans," being in reality a bean and not a pea. They have long been recognized as being highly suitable for soil renovating crops, whether planted in the spring, or as catch crops on stubble land, or inter-planted with corn or other crops. They are grown more largely in the Southern States, but in recent years their use as a soil renovating crop in the Corn Belt States has greatly increased. The last named section depends largely on the South to supply the seed for their plantings.

437. Harvesting Legume Hay. Peavine hay is very nutritious, but requires some care in order to cure with-



Fig. 192. Peanut Stacks stacked for curing. One bare vertical stack pole shown in foreground. Courtesy of Prof. A. D. McNair, United States Department of Agriculture.

out moulding. It should be put in small shocks when well wilted, or stacked around small vertical poles, the hay resting on cross pieces nailed to the poles or be piled on skeleton pyramidal frames, where the air can penetrate and dry it. Peanuts are plowed out by means of a plow with the mold board removed or a potato digger, which



Fig. 193. Alfalfa curing in shocks and in windrows. (Ohio)

lifts them out of the ground. The plants are piled around vertical poles with the nuts on the inside. (Fig. 192). These may stand some weeks and then be stored loose, or threshed, and the vines baled. Lespedeza hay, alfalfa hay, and all those hays which are fine, or of medium fineness can be handled with modern hay-making machinery. The coarse hays can seldom be handled in this way and therefore the labor and expense of harvesting is greater than for the fine hays.

CHAPTER XLII

CULTIVATED GRAINS

438. Wheat, which was probably the cereal first cultivated by the early civilization living in the countries bordering on the Red and the Mediterranean Seas, has spread throughout the world. Rice and wheat were the grains of the early Eastern civilization. Corn was the great food plant of the natives of Central and North America. Thus we see how it has happened that rice, wheat, and corn are the great grain crops of the world.

439. The Word Corn was originally applied to any hard edible seed, grain, or kernel. In Biblical language, just as to-day to an Englishman, "ears of corn" means "heads of wheat." In Northern Europe "a cornfield" refers to a field of rye, and in Scotland, to oats. In other countries our corn is "Maize or Indian Corn," as it was first called by the early American explorers. In the same way "Kaffir Corn" and "Milo Maize," and other grain plants have been named by the Old World to distinguish them from their staple grain.



Fig. 194. Corn cut to save stover. The shocks are placed wide apart to facilitate early seeding to wheat.

Courtesy Prof. Hartley, United States Department of Agriculture.

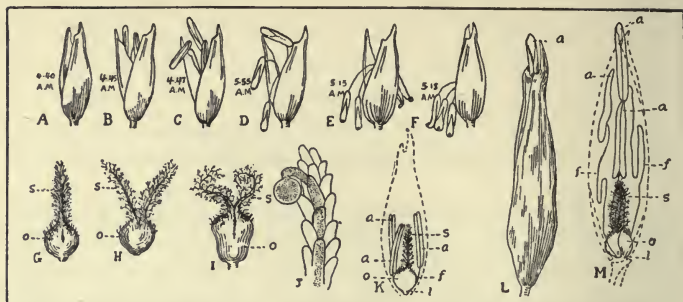


Fig. 195. Blooming of wheat flower. *A* to *F* opening and closing of flower; *G*, pistil, and *K*, pistil and anthers in positions at stage shown in *A*; *H* pistil at flowering stage; *I*, shortly after flowering; *J*, portion of stigma showing germinating pollen grain; *L*, a single flower just after flowering; *M*, section of same.—After Hays.

440. Pollination in Grains. In wheat, oats, barley, and most other grasses, the stamens and pistil are produced in the same flower. It has been found that the anthers shed their pollen and the stigmas become moist before the flower opens and are thus normally close fertilized. (§ 169). Prof. Hays found that wheat flowers open and close in the early morning hours, the operation consuming only 20 to 40 minutes. Study Fig. 195. In corn, the tassel produces the pollen bearing flowers. The silks usually appear before the pollen is shed from the tassel above. As a result corn is normally cross fertilized by pollen blown from nearby stalks. (See § 173).

441. In Germination and in the formation of the roots, cereals show a peculiarity that is important to know when their seeds are to be planted. The first stages of germination are as shown in Figs. 9 and 10. The shoot end grows up and forms a second whorl of coronal roots that are permanent, the seedling roots eventually dying. (Fig. 196). The length of the first internode varies, according to

the depth of covering. If the seeds are covered deeply, it will grow to within about one or two inches of the surface before forming the permanent roots. It will thus be seen that deep covering of grains does not make the plants deep rooted, and only seems to reduce their chances of success (§ 32). The root system of cereals is composed altogether of slender, much branched roots. There are no heavy tap roots as in alfalfa. (See Figs. 32 and 203).

442. The Best Varieties of Cereals are strains that have been continuously and carefully selected and thus acclimated in the climatic belt in which they are to be grown. High yielding varieties of corn and wheat from moist climates usually give lower yields in dry climates than acclimated native sorts; corn and other grains from dry climates, however, will sometimes out-yield native strains in moist climates, if the change is not too radical. In many sections of the South, seed corn is purchased from the North, with the idea that it will give earlier maturity and therefore larger yields. It does give *earlier maturity*, but it has long been established that improved native varieties give *more bushels* of corn. (See Fig. 188.)

443. Improvement of Varieties. Nearly

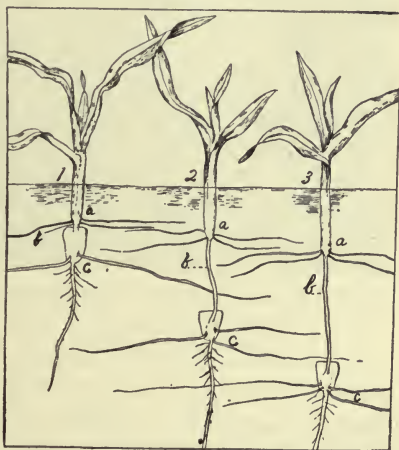


Fig. 196. Diagram of germinating corn when planted at different depths. 1, when planted 1 inch deep; 2, planted 3 inches deep; 3, planted 5 inches deep; c, seedling roots; a, permanent roots; and b, first internode the length of which is determined by depth of covering of seed.

all the valuable varieties that have been introduced, have resulted from the careful multiplication of seed from selected plants. The average grain grower may not care



Fig. 197. Head rows of wheat showing differences that may be noted when seed from different stools are planted in adjacent rows.

Kansas Agricultural College.

to take the time to make the head row tests to improve his seed, but it would be more profitable to do so than to continually plant common, mixed, field run seed, as is commonly practiced. When the seed from selected heads of the same variety of grain are planted in adjacent drills, we have a chance to compare the differences in their progeny. The seed from the best yielding head rows are used to plant

increase blocks and so on until enough seed is secured to plant a large field. (See Figs. 197 and 198).

444. Preparing Land for Small Grain. As a general rule, breaking land intended for small grain well in advance of seeding, will give considerably larger yields than late breaking. Breaking to a depth of less than 4 to 5

inches or greater than 8 to 10 inches is not often desirable. The advantages that follow early breaking are due to the increased amount of moisture stored and the encouragement given to the formation of nitrates in the soil. (§ 128).

445. Early and Late Plowing. Many experiments have been made that show *how great* the gain is when



Fig. 198. Increase blocks of wheat and oats planted from seed grown in head rows. Increase blocks planted in this way afford another opportunity for comparing quality and yield.

Courtesy Prof. Frank Spragg, Michigan Agricultural College.

early breaking is compared with late breaking. At the Oklahoma Experiment Station, three plots were plowed on dates indicated in the table in § 446. In the early plowing, the soil was moist and readily formed a mellow bed that absorbed and largely retained the summer rains. The medium late breaking broke up lumpy and was drier, while the very late breaking was so weedy, and broke up so lumpy that it required about eight times as much labor to get the land in reasonably fair condition for seeding.



Fig. 199. Wheat growing on plot No. 1, which has been merely double disced and continuously seeded to the same crop. Compare with Figs. 200 and 201.

446. All were planted on September 15th. On the early plowed plot, germination was prompt and regular, and the plants went into the winter with a good start, and as a result grew off earlier in the spring and matured their crop earlier. On the late plowed plots, germination was slow and irregular, due to lack of moisture and the unsettled condition of the soil. The following yields were obtained:

	Date of Plowing.	Yield per acre.
Early preparation.....	July 19th	31.3 bushel
Medium.....	Aug. 15th	28.5 bushel
Late.....	Sept. 11th	15.3 bushel

447. The early breaking was worth about 25c a day per acre over the late plowing. Results obtained at the Kansas Experiment Station indicated similarly a gain of about 40c per day in favor of early deep plowing, when compared with late, shallow plowing. Results are usual-



Fig. 200. Wheat growing on plot No. 6, which had had a heavy crop of rye plowed under, and deeply plowed and summer fallowed after each harvest. Compare with Fig. 199, and results noted in table in ¶449.

ly, but not always, so decidedly in favor of early preparation. Indeed, sometimes there is no gain whatever, but seldom if ever, any decreased yields result from early deep plowing.

448. Listing in Arid Sections is sometimes preferred to flat breaking, especially if the fields are level and do not wash. Prof. TenEyck reports the following results with wheat at the Ft. Hays Kansas Experiment Station:

YIELD OF WHEAT ON FLAT BROKE, LISTED, AND FALLOWED LAND

Soil Preparation	Yield per Acre in Bushels	
	Total in 5 Years	Average
Late fall plowed.....	59.9	12.
Early fall plowed.....	83.3	16.7
Early fall listed.....	104.4	20.9
Summer fallowed (2 plots alternated).....	107.8	23.6
Summer fallowed, each plot.....	53.9	11.8

449. Green Manuring. (See ¶ 131). Prof. Shaw of the California Experiment Station, reports the following results which show the possibilities of deep plowing, and

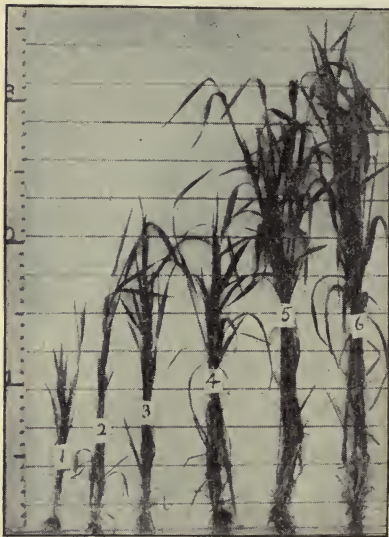


Fig. 201. Wheat plants from six plots treated differently, showing comparative development: 1, plot continuously seeded to wheat; 2, barefallowed; 3, horse beans grown and plowed under after previous crop; 4, Canadian field peas grown and plowed under; 5, rye and vetch grown and plowed under; 6, rye grown and plowed under.

a single green manuring on sandy soils naturally lacking in the qualities that humus gives. First a number of plots were summer fallowed, and in the fall plowed to a depth of 6 inches, harrowed and seeded as indicated in the table, except No. 1, which was sown to wheat continuously and only double disced after each harvest. The other plots were deeply plowed after each harvest and summer fallowed. Compare Figs. 199, 200 and 201. Also ¶ 143.

YIELD OF WHEAT UNDER DIFFERENT SOIL TREATMENTS

Crop Grown and Treatment Given in First Year	Yield per Acre		
	2d Year	3d Year	Average 2 Years
1. Wheat after wheat double disced	15.7		
2. Bare fallow	28.	38.6	33.3
3. Horse beans, (turned under)light	35.3	40.0	37.6
4. Canadian field peas (turned under) . . .light	33.7	39.3	36.5
5. Rye and Vetch (turned under)heavy	50.7	57.3	54.
6. Rye (turned under)heavy	51.3	53.3	52.3

450. In the results, the increased yield was in proportion to the amount of vegetable matter turned under. The advantages of deep plowing and green manuring were noticeable. Similar tests made on heavier land, richer in humus, did not show such decided increase.

451. The Fungus Diseases of Cereals of most importance are the rusts and smuts. The rusts, (Fig. 88) do greater damage, and unfortunately no satisfactory means of control are known. The selection of varieties showing reasonable resistance is the best safeguard against loss from rust. Every class in Agriculture should make the treatments to prevent smut in wheat, oats, barley, and sorghums. (See ¶ 222). There are a number of different species of grain smuts. There are several species peculiar to wheat, and likewise other grain crops. Some kinds may be prevented by treating the seed grain with a dilute solution of formalin, while with others the treatment with hot water will be effective. The cost of treating seed grains is small.

451a. Loss from Grain Smuts. Visit grain fields just before harvest. Mark a square yard and count the stools, noting the number smutted. Calculate the per cent of loss. How much could a farmer afford to pay for seed wheat or seed oats reasonably free from smut?

451b. How many acres in the school district are planted to wheat, oats, barley, rye, and sorghum? What was the highest, the lowest, and the average yield for each grain? What was the average loss caused by smuts for each crop? What would this amount to for the school district? How does this sum compare with the cost of the school house?

CHAPTER XLIII

WHEAT, OATS, RICE, BARLEY AND RYE

452. Wheat is most largely grown in cool, temperate climates, though it is grown to considerable extent in the tropical sections of all continents. Its winter growing habit and early spring maturing, make it especially well suited to the higher and drier sections of the Middle Western States. While the varieties adapted to fall seeding are grown almost exclusively in the warmer wheat sections, there are many varieties adapted to spring seeding grown in the colder climates.

453. The Wheat Genus includes eight types: The (1) einkorn, (2) spelt, (3) emmer, (4) poulard, and (5) Polish wheats are forms that are very hardy and drouth-resistant, and are grown to some extent to-day in dry sections, but more for feed for live stock than for human food. These grains produce a very inferior flour. They were largely cultivated in ancient times throughout Egypt, Greece, and the Roman Empire.

454. The (6) Common Wheat includes the varieties largely cultivated throughout the world as bread wheats. Their larger use is due not only to their greater yielding power, but because of the superior quality of their flour for making leavened bread. This quality is due to the presence of gluten, which causes the flour to form a dough when mixed with water. This on leavening and baking forms a porous bread. Leavening is produced by the formation of carbonic acid gas in the dough, either by yeast or from baking powder. The (7) Club Wheat

varieties are readily distinguished by their short, compact, club shaped heads. Their milling qualities are similar to common wheat.

455. (8) Durum Wheat varieties have noticeably broad, smooth leaves. The heads are large and often so heavily bearded that they resemble barley. The grains are large and very hard and have more gluten and less starch than common wheat. Durum wheat is sometimes called "macaroni wheat" from the fact that it is particularly well suited and largely used for making macaroni and other paste products. The best durum wheat flour makes an excellent quality of bread, though not naturally so white as bread from common wheat.

456. The Hardness and Texture of the grain vary not only in the different varieties, but with the climate and season in which the wheat is grown. Hard wheat varieties which characterize dry regions, become soft when grown in moist climates, and vice versa. This explains why the fall sown wheats grown east of the Mississippi River are largely soft wheats, and the wheat from the drier sections of the West, largely hard wheats. Hard wheat grains show a dark, horney appearance on the exposed surface when cut across, while the cross sections of soft wheat are white and starchy. Varying with the kind, quality, and grade of wheat and the milling processes, the out turn of mill products are about as follows: Flour usually 70 to 75 per cent ranging from 65 to 80 per cent. The flour is usually run in two or more grades; bran 15 to 20 per cent; shorts and middlings, 5 to 8 per cent.

457. Oats grow rapidly, a habit made possible by their large development of leaves. Prof. King reports that oats require more water to make a pound of dry matter than wheat or corn, his experiment indicating 504 pounds

of water for oats, 464 pounds for barley, and 277 pounds for corn. (§ 106). In the dry warm climates, red oats are more successful than the white oats, and probably require less water. In sections far enough south to allow fall seeding oats are valuable, not only as a grain crop, but as a winter grazing crop; in fact they are often grown for this purpose alone.

458. Preparing Land for Oats. Oat yields are affected more by the nature of the soil, and the rain-fall during their growing season, than by the manner in which the soil is prepared for seeding. They give their best returns on heavy stiff lands. Fertilizers like potash and phosphates, that tend to increase the grain rather than the stalk are preferred. Nitrogenous fertilizers increase the natural tendency to make a large growth of stems and leaves, often causing the stems to lodge.

458a. Classes and Varieties of Oats. The cultivated oats belong to three groups as follows: A. *Common or Branched Oats* which include most of the cultivated varieties, commonly classed as white oats in the grain trade. Some varieties have dark or even black grains. The panicles or heads are open and spreading. B. *Tartarian or Side Oats* have erect, close panicles, the spikelets being on short branches that hang to one side of the head. This form includes but few varieties that are generally cultivated. C. *The Red or Southern Oats*, originally from Southern Europe, are often called "rust-proof oats" because of their comparative resistance to rust. They are generally used in the South, where the more vigorous growing white oats do not thrive. Red oat varieties are growing in favor with northern farmers, due to their early maturing habits. Their low-growing, stout stems, comparative resistance to rust, ability to stand up well and avoid lodging, drouth resisting qualities, and large grains make them especially popular in the South.

459. Rice is said to be the principal cereal in the diet of nearly 800 million people, which is more than half of the world's population. It makes a healthful, economical,

appetizing food and its use in American homes is rapidly increasing, especially as a base in preparing side dishes. It was the most important grain in China 3,000 B.C., but was not known to the ancient Egyptians. It was introduced into Italy in the Fifteenth century and into the Virginia Colony in 1647, and was first grown in the United States in a garden in Charleston, S. C. in 1694.

460. Most of the American rice is grown in South Carolina, and in the Gulf prairie regions of Texas and Louisiana. It is successfully grown in inland locations in South Carolina, California, Arkansas, and as far north as Southern Illinois. Rice is usually and most successfully cultivated under irrigation. Water is necessary not only for the best development of the crop, but to keep down weeds. In oriental countries rice is germinated in beds, and the seedlings transplanted by hand, but in America the ground is prepared, seeded, and harvested by the same machinery used in handling other cereals. The fields are usually kept covered with water from the time plants are a few inches high until near the harvest period.

461. Barley and Rye are largely grown in Europe and in a few sections of the United States. While barley is largely used in the manufacture of beer, hardy varieties are often grown for winter pasture, and to produce grain for feeding. In some sections, barley is mown when "in the boot" for hay. Rye has similar uses. Because of their hardiness and vigor, they are both much grown to furnish winter pasture and cover crops, the production of grain being a secondary consideration.

CHAPTER XLIV

CORN

462. The Corn Plant is an interesting one because it is the most important American crop. It is valued not only as a producer of grain, but forage also. From the grain we get meal, various forms of breakfast foods, starch, glucose made from starch and so largely used in candies and sirups, corn oil largely used in making rubber tires for vehicles, and many other useful products. It is an annual plant that has a reasonably fixed period of growth from germination to maturity, and dies before the growing season ends. Some of the tall growing forms found in tropical America require over 200 days to mature their crop. (See Fig. 188).

462a. Species and Varieties. Corn includes the following species, distinguished largely by the amount of horny endosperm, in the fruit or grain (§ 18).

a. Pod Corn has the grains as well as the ears covered by shucks. This is supposed to be the primitive form from which the cultivated varieties have been developed.

b. Pop Corn is recognized by the smallness of the grains, and the hard horny endosperm extending to the top of the grain. When suddenly heated to high temperatures, the endosperm everts, with a "pop," forming the familiar soft, starchy mass.

c. Flint Corn has a glossy capped grain, due to the horny endosperm extending to the top of the grain. Many varieties of this class mature in 90 to 120 days or less. Because of this early maturing habit they are largely used as the staple field corn of the New England States, and in many sections of Canada. They do not yield so well as dent varieties and are being replaced by the development of early maturing dent varieties.

d. Dent Corn is the type cultivated almost exclusively in the

CHAPTER XLVI

COTTON

491. The most important product of the cotton plant is the fiber. Wool and silk are the animal fibers used in spinning threads for soft fabrics. Cotton, flax, hemp, and jute are vegetable fibers used in textile manufactures. The coarser fibers, largely used in cordage and bag manufacture, are hemp, jute, sisal, and some thirty others of minor importance. It should be noted that cotton is the most important fiber in the world, and that it is most largely grown in the United States. The manufacture of cotton alone gives employment to more people than any other single industry.



Fig. 211. A cotton field on prairie land showing uniform, fruitful, stalks and burs with storm-proof qualities. Grown from pedigreed seed.

492. History of the Cotton Industry. Cotton has not always been the important plant that it now is. It was first known to our civilization in Southwestern Asia and China, and is said to have been first introduced to the countries bordering on the Mediterranean Sea, during the time of Alexander the Great (356–323 B.C.). Species of cotton, different from old world forms, were found growing wild, and sometimes in cultivation in Mexico, and the West Indies, and various parts of South America when these countries were first visited by Europeans. However, owing to the great expense of removing the lint from the seed by hand, wool, flax, and silk continued to be the most important fibers until near the beginning of the 18th century.

493. The invention of the spinning frame in 1769, by Richard Arkwright and the cotton gin in 1794 by Eli Whitney, made it possible for cotton to be the basis of large manufacturing industries, not only in America, but also in Europe. It soon became, and has remained our largest export production, and to-day brings more money to the United States than any other class of exports.

494. The Growing and Fruiting Habits of cotton are different from the grains. The latter are annuals and have a reasonably fixed growing period in which the maturity of the fruit is the beginning of their death. Cotton grows and fruits as long as conditions continue favorable. The stalk has a stout central stem, usually from 1 to 5 feet tall, varying with the soil, rainfall, and variety of cotton. The branches are of two kinds; (a) *fruiting branches* which form a bloom in the axil of every leaf, and (b) *vegetative branches* which, like the stem, do not bear flowers, but only leaves and fruiting branches. (See Figs. 212 and 213).

495. Characters Considered in Selecting Seed. As a flower is produced at every node on fruiting branches, it is plain that branches with short internodes will form flowers more rapidly than branches with long internodes, and short jointedness is therefore an indication of a tendency to *rapid fruiting*. In some plants the first fruiting branches are formed early and close to the ground, but in others later and higher up on the stem. We can thus see that the latter type of stalk would be *late* in beginning to form fruits, and the former *early*. Again, in some varieties we find that the fruiting branches are short, and cease to lengthen after forming just a few nodes. Such branches are said to have a *determinate* growth. In others the branches continue to grow and flower thruout the season, and are described as *continuous* growing or fruiting branches. As the fruiting period is limited by the length of the growing season, it is desirable to select seed from plants that begin to fruit early, fruit rapidly and continuously. Such plants produce larger crops than stalks with opposite characters. The method of selecting high yielding strains is similar to the plan of improving corn by the ear-to-row test.

496. The Size of the Bolls, and the character of the opened burrs are closely associated with the earliness of maturity, difficulty of picking, and resistance to weather damage or "storm proof" quality. Burrs of large bolls are more storm proof than those of small bolls, and they are a great advantage in picking, for it is easier to pick a pound of cotton when the bolls average 40 to 60 to the pound, than in cotton where 120 to 150 are required. Each boll has usually 4 to 5 cells in which the locks or lint bearing seeds are produced.

497. Species and Varieties. There are a number of

well marked types of cotton in cultivation. The cottons cultivated in Egypt, India, China, and Central and South America are all noticeably different from the American upland cotton. The upland varieties are adapted to a wide range of conditions, producing a fiber $\frac{7}{8}$ to $1\frac{3}{16}$



Fig. 212. Cotton stalk with vigorous vegetative branches and short determinate fruiting branches. Type of late slow fruiting stalks.

inches long. The long staple varieties having fibers $1\frac{1}{4}$ to $1\frac{1}{2}$ inches long are successful only on rich soil in humid regions. Sea Island Cotton, which is readily distinguished by its yellow blossoms, came originally from the West Indies. It has silky fibers $1\frac{1}{2}$ to 2 inches long and is successfully cultivated in just a few localities near the coast in South Carolina, Georgia, and Florida. Besides

the American types a form of Egyptian cotton is grown to a limited extent in California and Arizona.

498. Cultivation. Bearing in mind the continuous growing habit of the cotton plant, and the relation of this



Fig. 213. Cotton stalk with vigorous fruiting branches and one slow growing vegetative branch. Type of early, rapid continuous fruiting stalk. Note that the first fruiting branches are low and continuous fruiting.

to fruiting, it is plain that the first consideration should be to provide the conditions that make growth continuous and normal throughout the growing season. Aside from the natural richness of the soil, the regularity of the supply of moisture is most important. (§ 105). While cotton is classed as a drouth resisting crop, it is well to remember

that a liberal amount of moisture is essential for continuous fruiting and therefore for large yields.

499. The Light Relation of the fruiting branches is probably the second most important feature to be considered in caring for a cotton crop. Cotton plants do best in warm, sunshiny weather. The normal healthy growth of the fruiting branches is especially important. Plants should never be so thick that the leaves on these branches shade each other very much. On upland or poor land where cotton stalks grow only 18 to 24 inches high, the plants may be quite close together, 10 to 18 inches in the drill, and not injuriously shade each other. On heavy bottom or other lands, greater space between plants should be given in order to allow the light to reach the lower fruiting branches. It may be noted that the rule for spacing cotton according to the richness of the land is the opposite of that for corn. Why? (§ 149-466).

500. Shedding of Blossoms. Cotton yields are often reduced by the falling off of many blooms and young bolls, leaving the branches unfruitful. This is not well understood, but it is probably influenced by irregularity in the moisture supply due to dry weather, hot winds, or showers. Shedding may be serious either when growth is very rapid or very slow. Sometimes shedding is attributed to improper fertilization of the flower by the pollen, sometimes to poor nourishing of the blooms, either from rapid growth or dry weather. (See § 158-160). The time consumed from the beginning of the bud to the opening of the flowers is usually about 3 to 4 weeks. (See Fig. 85). The time from the opening of the flower to the maturity and opening of the boll is 30 to 50 days. When the flowers open, usually about sunrise, they are creamy white in upland cotton and yellow in Sea Island

cotton. They turn pink, through the day and close towards nightfall. The flowers are normally self fertilized, though considerable cross fertilization is brought about by the visits of insects, humming birds, etc.

501. Preparing Land for Cotton. Cotton farmers are not agreed as to the comparative advantages of flat breaking, listing, or double listing in preparing land for a cotton crop. Deep fall breaking of cotton land is very desirable, but is often prevented by delays in picking the previous crop. This condition can be partially avoided by rotating cotton with small grains, cow peas, peanuts, or corn, but unfortunately much land is planted to cotton from year to year.

502. Seedage. Seed are often planted on "the level" on harrowed land. In very dry windy sections, the seed are put in slight lists, while in moist sections subject to excessive rains, the seed is planted on slightly raised beds. Formerly it was the practice to sow cotton seed by hand in drills, using 2 to 3 bushels per acre. Now, owing to the regularity of dropping and covering by machine planters, only a fourth to a half bushel of seed is used to plant an acre. This thinner seeding is not only best for the young seedlings, but greatly reduces the expense of subsequent thinning.

503. Fertilizing Cotton. Lint cotton makes an exceedingly light draft on the necessary mineral food elements stored in the soil. (Fig. 45). The seed, however, draw more heavily than any other field crop on the supply of nitrogen, phosphates, and potash. It is probable that the very general habit of selling the cotton seed off the farm is doing more to exhaust the natural fertility of southern farms than even the washing or leaching of the soil. The soils of the older Southern States were once

rich but must now receive regular applications of fertilizers containing phosphates, nitrogen, and often potash, in order to produce reasonably good crops. Cotton is a "clean cultivated" crop, and returns but little organic matter to the soil. Barnyard manure is always beneficial, but is not abundant in cotton growing countries because the stock are not kept in barns as they are in the colder sections.

504. Harvesting and Ginning. The cotton as it is picked from the stalks in the field is called seed cotton. It is picked by hand and hauled to gins in lots of 1200 to 1700 pounds, — sufficient to give a bale of about 500 pounds of lint. Machines have been invented that successfully harvest cotton, but have not yet come into general use. The gins separate the lint from the seed. The proportion of lint to seed cotton is usually about 33 percent, varying from 28 to 42 percent lint in upland cotton, and only 20 to 30 percent in Sea Island cotton. As seed are worth only about one cent a pound, and the lint 10 to 15 cents and upwards, it is plainly evident that high percent of lint is a valuable quality. After ginning, the lint is pressed into rectangular bales, wrapped in coarse burlap or bagging, and tied with steel ties. In this condition it is usually sold by the farmer in local markets to cotton dealers who have the bales compressed and shipped to mills or cotton merchants. The "round bale" pressing, while seemingly more desirable than the usual form, is not largely used.

505. Cotton Seed Products. Cotton seed were formerly discarded, because, like the tomato, they were thought to be poisonous. To-day, however, cotton seed products are staples on the world's markets. Cotton seed meal is very rich in protein and is exported in large quantities

to European countries for feeding and fertilizing purposes, when perhaps it should be similarly used in the south to keep up the fertility of her own fields. (See analysis in appendix.)

506. In recent years cotton seed meal is used in making bread and cakes. It is mixed with wheat flour to secure leavening quality. The general use of cotton seed flour in bread making is to be encouraged, not only because it is cheaper, but because it is nearly 5 times richer in protein, and therefore more nourishing than wheat flour. (See ¶ 335.) The hulls have a low feeding value, but are largely used as a roughage for all kinds of stock. Cotton seed oil is valuable for shortening in breadmaking, being about one third more efficient, and usually much cheaper than lard, or lard compounds. It is now largely used as a salad oil in place of olive oil. The low grade oils are used in making soaps and washing powders.

507. Mexican Boll Weevil. The cotton root rot fungus, (¶ 224), the boll worm, and other important cotton diseases mentioned in chapter 23, have been known for many years. Another serious insect pest of cotton is the Mexican Boll Weevil. (Fig. 104.) In 1904, it was established that the Texas cotton crop had been reduced to nearly half by the ravages of the boll weevil. This damage represented many millions of dollars, and for a time the insect seemed to threaten the future of the cotton



Fig. 214. Late Fall boll showing how weevils hide between boll and involucre or "square."

industry. The first public boll weevil convention was held at Victoria, Texas, in 1895, and in 1903 the Texas Legislature offered a reward of \$50,000 for the discovery of a remedy for the boll weevil. Later, several important conventions were held in Dallas, Texas, and Shreveport and New Orleans, La. The Federal and State governments made large appropriations, and a corps of entomol-



Fig. 215. Cotton growing area of the United States exclusive of Arizona and California, with lines in heavier shaded portion showing spread of Mexican cotton weevil.—After W. D. Hunter, U. S. Dept. of Agriculture.

ogists and cotton specialists began investigations and the result was the present satisfactory means of control.

508. The Spread of the Boll Weevil. Figure 215 shows that the advance of the boll weevil has been northward and eastward, into the humid regions, rather than westward. There is no doubt that the weevil will continue to advance rapidly eastward, but will move slower toward the north, owing to the climatic obstacles that the weevil will have to overcome. The dry summer and cold winters of 1910-1912 reduced somewhat the northward advance as

the map shows. The dry weather, cold winters, and open nature of the West seem to limit the westward movement.

509. Life History. The adult insects leave their winter shelter early in the spring and deposit eggs in the



Fig. 216. Mexican Cotton Weevil. *B*, appearance of normal square or flower with involucre; *A*, "Flared" square following deposit of egg in unopened bud; *C*, Part of flower-bud removed to show larva. After Dr. W. D. Hunter.

flower-buds. When the egg is thrust into the flower-bud ("stung" as it is sometimes improperly called), the "square" or involucre is soon "flared," as shown in Fig.

216, and shortly drops to the ground. In about 25 or 30 days from the laying of the egg, the mature weevils emerge from the fallen flower-buds and start a new generation. Thus a few weevils, starting early in the season, may, if

conditions are favorable, produce enough weevils to destroy a field of cotton. The adult weevils hibernate in winter in unopened bolls or under any kind of trash that may be available, especially in the leaves of nearby woods. During the following spring, they begin to emerge in considerable numbers after the first few weeks of warm weather. They feed on the tender portions of the young cotton.

510. By using improved, early, rapid fruiting varieties of cotton, and cultural methods that favor the same results, early planting, wide rows, frequent tillage, gathering fallen squares, and other measures,—a fair yield of cotton may be secured in the presence of the weevil. More than thirty species of birds are known to use the boll weevil as food. Ants, parasitic wasps, and flies, birds, snakes, and climatic agencies assist man in his fight to keep this pest under control. Dry summer weather and prolonged cold winters greatly retard the increase of weevils.



Fig. 217. Day and night position of leaves of cotton plants. No. 1. Expanded in bright sunlight ready to receive full benefit of the sun's rays. No. 2. Night position supposed to be an adaptation to reduce evaporation of moisture and radiation of heat. From photographs of same plant from the same position.

CHAPTER XLVII

VEGETABLE GARDENING

511. Some vegetables and fruits should be grown "just for home use" if only a back yard is available. To produce an abundance of vegetables requires but a small plot of ground and little labor. Not much space is required for even berries and orchard fruits. They give a degree of satisfaction and refinement to home life that money cannot buy. Except for the occasional plowing and spading, the home garden work may be cared for by the women folk, who may thus bring food to the family table and strength, and buoyancy of spirit to themselves.

512. The First Essential for Gardening is a rich, warm, sandy loam soil. If opportunity allows, preference should be given to southern exposures. Where excellence



Fig. 218. "When youz thump 'em and dey goes 'kerplunk' dey's ripe."

Courtesy Department of Horticulture, Purdue University.

in the individual plants and fruits is especially important, as it is in vegetables, particular attention should be given to the selection and improvement of the soil. Early maturity, large size, succulence, and tenderness are desirable qualities which are associated with rapid growth. This comes when the land is kept in good tilth (§ 75) and well supplied with humus. Sandy loamy



Fig. 219. Tomatoes in a cold-frame ready to transplant. Plants should be gradually hardened off before transplanting, and just before moving should be thoroughly watered.

Courtesy Department of Horticulture, Purdue University.

soils are preferred for gardens because they warm up early in the spring and are easy to keep in good tilth. However, they are not absolutely essential for good gardens. Whatever the nature of the soil may be, it should receive heavy applications of manure, be plowed deep and kept clear of weeds by frequent surface cultivation.

513. Forcing. Forcing is a term given to the growing of plants under artificial heat in order to secure

early vegetables or flowers. We often grow them slightly beyond their seedling stage under forcing conditions, using hot beds, cold frames (§ 36), in-door window boxes, or in garden flats (§ 15) that are kept in-doors in cool weather and exposed to sunlight in fair weather. As the seedlings grow larger, they may be replanted into small pots, cans or boxes affording more space and allowed to grow until the season for planting in the open arrives.

514. Classes of Garden Crops. In studying the cultural requirements and use of garden crops, we may for convenience divide them into a number of groups according to their cultural requirements. In looking for an explanation of why some crops thrive in some seasons and not in others, or in some localities and not in others, it will probably be found in a consideration of their moisture and temperature requirements.

Our mothers classify vegetables according to their use and flavors. The following classification will help us to group the vegetables according to the similarity of their cultural requirements, and will help us in understanding and applying the detailed cultural directions given in gardener's manuals and to appreciate the intelligence that is sometimes mistaken for skill in the gardener.

515. Cool Season Vegetables, include plants that are not injured by at least light frost. Some are not injured by even light freezing temperatures of short duration, and will thrive in moderately cool weather. Crops belonging to this group may be planted in the open early in the season. Some forms, like cabbage, cauliflower, collards, celery, etc., may be grown in the winter or fall months in mild climates. We may subdivide this group as follows:

(a) *Early Cool Season Vegetables* are frost hardy,

early planted vegetables that have a short growing season and mature before the season for hot weather arrives. They do not develop crops of good quality in the dry air of summer. They are hardy, however, to light frost and may be planted in the open quite early. Included in this group are garden cress, kohlrabi, leaf lettuce, radishes, mustard, peas, spinach, and turnips.

(b) *The Late Cool Season Vegetables*, like the above, are also frost hardy and favored by cool weather but require a longer time to mature. They are also easily injured by early hot weather. To avoid this possibility, it is usual to grow their seedlings by forcing in the late winter and to have the plants well started and ready to set in the open in early spring. It is a "transplanting group" and includes cabbage, head lettuce, and celery. They are plants grown largely for their foliage.

(c) *Open Season Early Planted Vegetables* require a still longer period to mature. They are favored by cool moist weather, particularly in their young stages, but once established will thrive in warm summer temperatures. Here belong the potato, beet, carrot, parsnip, salsify, onion, and the perennial vegetables, asparagus and rhubarb. It will be noticed that they are valued because of their fleshy roots, stems or leaf stalks. The vegetables in this group are popular because they have comparatively few enemies, have a long period of edibility, and are easy to care for because they endure moderate extremes of heat and cold.

516. Warm Season Vegetables include crops that are sensitive to even light frost and do not grow well in even cool weather. They are all native of warm climates and require summer temperatures for rapid growth, and the development of large yields and good quality. We

may divide them into a short and a long season group:

(a) *Short Season summer Vegetables* are usually planted in open ground after the frost and cool night season is safely passed. They may be planted in the open and still have time to mature in regions having short summers. In this group may be mentioned string beans, lima beans, sweet corn, cucumbers, muskmelons, watermelons, squash, pumpkin, okra, etc. The plants included in this group are valued for their fleshy fruits. These crops demand warm weather.

(b) *Long Season Summer Vegetables* require a long season of summer temperatures for full development and large yields. In northern climates having short summers, it is necessary to start the plants under glass considerably in advance of the warm season in order that they may mature ahead of early fall frosts. Their seedlings are quite delicate, which is another reason for growing the early stages under forcing conditions. In this group we have the tomato, egg plant, pepper, etc.

517. What Vegetables to Plant. For a home garden a continuous supply and a variety of vegetables are desirable. A dozen young plants properly cared for may suffice for one time.



Fig. 220. Cabbages are not hard to grow if the plants are given a good start and good cultivation.

We do not want to be compelled to eat cauliflower merely because it is in season, or to attempt to fatten on beans when we crave a salad. There are varieties of peas, beans, etc., that mature their crop gradually through a prolonged period, and are known as "kitchen garden" varieties. Others mature their crop in such short periods that the harvest is completed in two or three pickings and are known as "market varieties."

517a. Plan a Kitchen Garden. Secure several seed catalogs and note carefully the descriptions of the different varieties of lettuce, radishes, beans, etc., including all the vegetables you wish to grow. Also secure information from local gardeners about the different kinds and the usual time elapsing between seeding and harvesting.

Make a list in column of the varieties you desire to grow, putting the earliest planted sorts at the head of the list as follows:

Kind of crops	Variety	Usual date of planting	Usual date of harvest	No. of days planting to harvest

517b. Classify the plants given in the list mentioned above, using the diagram given below. When the list is made, compare the cultural requirements of the plants in each group.

	Cool Season Crops			Warm Season Crops	
	Early cool season crops	Late season crops	Open season crops	Short season crops	Long season crops
Salads.....					
Succulent fruits.....					
Roots.....					
Vines.....					
Legumes.....					
Relishes.....					
Savory herbs...					

518. Market or Trucking Gardens. People who live in large cities often do not have room for even a

back yard garden. Before the development of rapid transporting facilities, cities depended upon small gardens in near-by communities for their vegetable supplies. The old-time market garden, however, that formerly occupied a large place in the outskirts of the cities, growing a little of all the different kinds of vegetables, has been largely succeeded by the specialist growing large acreages in celery, cabbage, cauliflower, tomatoes, etc., in localities well suited to these crops. The supplies are shipped in car lots to large cities, in refrigerator cars when necessary. Early strawberries, lettuce, cauliflower, etc., are grown in the winter in California, Texas, and Florida, and shipped to all parts of the nation in the winter months. Later in the season the central states, followed by the northern states, may ship strawberries and other fruits back to the South.

519. Radishes and Lettuce. Prepare a bed to grow radishes and

lettuce. Secure several varieties of each from the usual sources and follow planting directions as given on the seed package. If the school is not blessed with a garden they may be planted in the home garden. Correlate the work with these crops with our plant and soil studies. Use a notebook, making dated notes. Measure the area planted to each crop, if only a foot, and likewise the crop harvested.



Fig. 221. Beans come in early and every one looks forward to the season's first mess.

520. Tomatoes require a rich soil and warm temperatures for

rapid growth, especially seedlings. Plant seed in flats about one inch apart and transplant to pots or larger flats when second or third leaves appear. Much time will be lost if the plants are allowed to grow slender from crowding, poor light, or confinement in close spaces. Early started tomato and other plants should be "hardened off" before transplanting to the open. This is done by gradually exposing the plants to the cooler night temperatures and being less liberal in supplying water to the pots.



Fig. 222. Potatoes should be planted deep. On left, planted only two inches deep, and as a result some were sunburned. On right, planted four inches deep—deep enough for the potatoes to be protected but still easy to dig. Note the growth of roots.

521. Irish Potatoes are grown in every state in the Union. In the northern states the crops are stored and used through the year. In the South two crops are produced. The spring crop is usually rushed to market to get the benefit of high prices. The fall crop is usually marketed more slowly, a part being saved for seed for the spring crop. The potato is a tuber, a thickened stem, which, like root crops, shows good results from deep breaking. Sandy loamy soils, rich in humus and plant fiber, are especially desirable. In the potato regions of the West rotations involving grain and the plowing under of the last cutting of alfalfa have proven to be highly profit-

able. Alfalfa turned under in this way is equivalent to 15 to 20 tons of manure. The seed potato, whether quarters or whole potatoes are used, should be deeply covered, as the tuber is formed on stems springing from the seed potato. Hence, if the potato is planted shallow, many of the potatoes in the crop will be so near the



Fig. 223. Germination and growth of corn at 55, 70 and 85 degrees F. 8 days after planting. After Prof. J. A. Jeffery, Michigan Agricultural College.

surface that they will sun scald. (See Fig. 222.) Potatoes run out if not selected. At harvest time the potato digger should be followed and seed saved from hills producing a moderate number of good-sized, smooth potatoes.

522. Frost and Rainfall Records. Write to the Weather Bureau, U. S. Department of Agriculture, for full information as to rainfall records and frost records by months made at the Observatory Station nearest you. Ascertain what month in the year has the heaviest average rainfall and what month the lowest.

523. Test Soil Temperatures in your garden (see ¶ 94). With a dairy thermometer note the temperatures at the surface and 3 inches below the surface once a week. Compare these with the germination temperatures given in ¶ 26.

CHAPTER XLVIII

SMALL FRUITS AND ORCHARD FRUITS

524. Strawberries, blackberries, raspberries, together with currants, gooseberries, and a few less familiar forms, are classed as small fruits. The first two are grown in nearly all parts of the country, while the others are successful only in the northern or cooler parts of the United States. The berries are easy to grow and popular because of their rich acid flavors. Grapes may be classed with the small fruits also.

525. Strawberries are easy to raise and easy to propagate. Light sandy soils are generally preferred,



Fig. 224. Ideal orchard condition. The trees are the only crop on the ground. Note the heading of the trees, and the absence of weeds and grass.

Courtesy Prof. C. G. Woodbury, Department of Horticulture, Purdue University.

though some varieties do well on heavy lands. Land intended for strawberries should be previously grown in some clean cultivated crop. Sometimes, especially in the South, the plants are set out in late summer or early fall. This gives plants strong enough to bear a heavy crop the following spring, if the season be favorable. In the North the plants are more usually set out in early

spring and allowed to grow through the first summer. Any flowers that come out are pinched off to keep the plants from being weakened by fruiting. Very strong plants are secured in this way which will produce heavy crops one year from



Fig. 225. A strong fruitful strawberry plant grown by the hill system. See colored plate.

Courtesy Mr. Will B. Munson.

planting. It is not advisable to attempt to secure more than two crops from the same planting because the plants become so thick that they are weak and not so fruitful.

526. Hills Versus Matted Rows. Where strawberries are planted in small areas in small gardens, it is usual to set the plants about 12 to 20 inches apart in

rows 3 feet apart. The runners or stolons put out by the plants are pinched off at regular intervals. This causes the formation of strong stocks which produce heavy crops of large berries. The hill system requires a great deal of care. Where large plantings are made the bed or matted row plan is followed. The plants are set in rows 3 or 4 feet apart. The first runners are cut off as in the hill system in order to produce stronger plants. The late runners, however, are trained to a bed 12-24 inches wide and are allowed to root.

527. Mulching. In the North it is usual to scatter a layer of straw three to five inches deep over the strawberry plants late in the fall. This gives protection to the plants against the injurious effects of rapid freezing and thawing through the winter. In early spring the straw is raked into the middles and under the leaves. If late frosts are threatened, the plants are covered for the night with straw. The straw in the middles acts as a mulch to retain moisture. In the lower South the plants grow through the winter and the straw is used largely as a mulch and for keeping the berries clean.

528. Selecting Varieties. There are many varieties of strawberries differing as to the quality of the fruits, time of ripening, and their adaptability to particular locations and soil. Some varieties of strawberries produce only pistillate flowers (§ 171) and will not produce fruit unless varieties having stamens are planted near them.

529. Blackberries, Raspberries and Dewberries are closely related and have similar fruiting habits. The roots are perennial but the stems grow one season and fruit the next. Through the first season the stems grow up and produce a number of lateral branches, especially if the shoot has been headed-in in the summer (§ 177).

In the following spring these branches bear the flower clusters, followed of course by the fruit. These stems, or canes, as they are sometimes called, die back after the harvest and new canes spring up from the old roots, which in turn bear the fruits in the following season. These old canes should be cut out shortly after harvest.

530. Blackberries are widely cultivated and are



Fig. 226. Everybody likes berries! — and they are so easy to grow. (Dewberries).
Courtesy Mr. F. T. Ramsey.

highly prized for their fruits. Dewberries have trailing vines and for this reason are not so popular as the fine quality of their fruit would suggest. The raspberries are confined largely to the north central and eastern states. They are not hardy in the extreme North or very fruitful in the South and West.

531. Gooseberries and Currants are low growing hardy shrubs. They are more successful in the north central and eastern states and are not generally grown

in the South. They are highly esteemed for their acid berries, which are gathered green and used for making jellies or canned and used for pies and sauces as wanted.

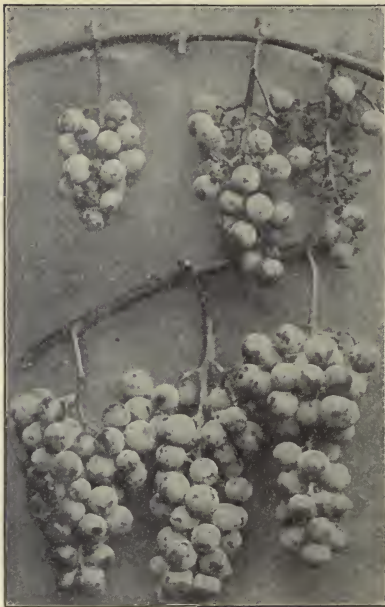


Fig. 227. Grape vines will bear an abundance of fruit but they must be sprayed to prevent black rot and other fungi. Top, from unsprayed vines; bottom, from sprayed vines.

Courtesy Mr. Will B. Munson.

Gooseberries are very fruitful in the more northern states and Canada.

532. Grapes are usually trellised, as indicated in ¶ 189. With the exception of the European grapes so generally grown in California, the varieties of grapes largely cultivated in America have been produced from the several native species, mostly during the last half century. The European varieties are not resistant to the phyloxera, a small insect that attacks the roots.

533. Grapes are easy to grow and succeed in most any climate, provided the proper attention be given to spraying to prevent damage from the several species of fungi, such as black rot (Fig. 92), downy mildew (Fig. 90), powdery mildew and anthracnose. The preventative is to spray with Bordeaux mixture, 5-5-50, at frequent intervals until near the ripening period.

For the later sprayings ammoniacal copper sulfate is used. Infection usually takes place with each rain, hence the idea is to always have the leaves, vines, and young fruits coated with the Bordeaux mixture. The frequency of the spraying will therefore depend upon the rains.

ORCHARD FRUITS

534. In Locating Orchards consideration should be given to the character and slope of the land, and the direction of the prevailing winds. If the plantings are to be large, with the idea of supplying distant markets, transportation facilities should be carefully investigated.

535. In Laying Out Orchards care should be taken to get the trees planted in straight checked rows. After the trees are pruned and set out (§ 185-188) it is well to observe the trees frequently to note their progress. Young trees are sometimes barked by rabbits, or the bark becomes sun scalded if they do not grow off readily. Protection from rabbits may be given by wrapping with paper or thin boards, etc. In apple orchards, owing to the spreading growth of the trees, it is usual to set them 30 to 40 feet apart. Pears grow more erect, and 20 by 20 feet is usually sufficient. The richness of the soils and the rainfall affect the size of the trees. Pome fruits are naturally slow to come into bearing. Apples may produce some fruits during the fourth or fifth years from setting out, though it is usually six to eight years before heavy crops are produced. Pears are slower, requiring six to ten years before heavy fruiting commences, depending somewhat upon the variety, soil conditions, and care given to the pruning of the trees and the cultivation of the land. (See § 159-160.)

536. Young Orchards should be well tilled and

efforts made to encourage rapid growth in the young trees. Other crops in young orchards are permissible if due precaution be exercised to see that they do not rob the trees of their moisture and light. Tall-growing plants like corn should never be planted in orchards. Low-growing crops like strawberries, peanuts, beans, and other garden crops are sometimes grown in young orchards and cause no injury if plenty of space is allowed for the trees. Hay or other untilled crops, as well as rank growing weeds, are not usual in successful orchards.

537. Ripening Wood. Orchard trees make their largest growth in the spring and early summer season. The branches do not grow in length very much in the late summer. The natural tendency is to use this period for ripening the young wood and storing food in the branches for the next spring's growth of stem and fruit (§ 159-160). The suggestion therefore naturally arises that the treatment of orchards should look carefully to conserving the spring moisture supply to the trees, and through the summer to protect them from extremes of dryness or other conditions that would affect the ripening of the branches. Disc harrows and other mulch-making implements are much used in tilling orchards. Sometimes orchards are sodded down, but as a rule this practice is not desirable, except on lands subject to washing.

538. Recognizing Fruit and Leaf Buds. Branches of the common fruit trees of the community should be brought into school and study given to the buds until all members of the class are able to distinguish the leaf buds from the flower buds and to see their relation to the season of growth and the age of the branches.

539. Harvesting and Marketing. Fruits are marketed in various ways, usually in half-bushel or bushel baskets or boxes and sometimes in barrels or even sold

in bulk, depending upon the quality of the fruit and the tone of the market. Progressive growers invariably use attractive boxes for shipping. Before packing for marketing, all fruits should be carefully graded. Large apples mixed with small apples sell at the price of the small apples. The varieties should not be mixed in the packages. In grading consideration should be given to uniformity of size, color, soundness, and ripeness. In harvesting and marketing peaches and plums, great care should be taken to avoid bruising the fruits.

540. The Pome Fruits include the apple, pear and quince. The apple is the most important fruit of the temperate region. The wide variation in the maturing periods of the many varieties, the adaptability of the fruit to keeping and transportation, and the productiveness and long life of the trees make it the most widely known fruit. It is grown commercially in nearly every section except in the extreme South.

541. The Pear is a fruit of great flavor and productiveness but is not so widely cultivated. They are not generally grown in the extreme North or upper plains region, but are popular in the more southern regions. Pears are much grown in arid regions where irrigation conditions occur. The quince is confined to the lake region and states farther east.

542. Apple Trees will need some pruning every year. The early pruning is for the purpose of making the head form low. If the trees are kept low much expense is saved in thinning and harvesting, and the spraying is much easier to do. The pruning of old trees will be for the purpose of removing dead or diseased limbs and thinning out the interior limbs to admit light, to encourage the formation of fruit spurs on the interior branches.

543. Spraying. The principal fungus diseases to be prevented in the case of the apple are scab, apple blotch, bitter rot and black rot. The insects affecting the apple most seriously are codling moth (Fig. 101) curculio (Fig. 95), San José scale (pronounced san hō-sā') (Fig. 100), and in some sections the woolly aphis and leaf aphis. The combination sprays usually applied are as follows:



Fig. 228. B. To control apple scab spray with Bordeaux mixture just before the cluster buds open. A. The time for effective spraying with arsenate of lead to control the codling moth is just after the petals have fallen.

Courtesy Department of Horticulture, Purdue University.

1st. Dormant Spray. When the trees are dormant, lime-sulfur wash or soluble oils may be used if scale insects are present. If serious fungus conditions are threatened, spray with copper sulfate solution. (See Fig. 102.)

2d. Cluster Spray, given just as the cluster buds open, but before the blossoms have opened (Fig. 228a). Use Bordeaux mixture for apple scab, black rot, and if canker worms are threatened add two pounds of arsenate of lead to the Bordeaux mixture.

3d. **Calyx Spray**, given just after the petals have shed and while the calyx end of the young fruits is still open and erect. Use Bordeaux mixture with 1 to 2 pounds of powdered arsenate of lead added for the special control of the codling moth, curculio and the less important insects. For the codling moth, it is especially desirable that the spray be made while the young fruits are open and erect. The codling moth usually lays the egg at the calyx end of the young fruits and if the spray is present, the young larvae get the poison with their first mouthful.

4th. **Later Sprayings** are given at intervals of two or three weeks depending upon conditions, using Bordeaux mixture to



Fig. 229. A peach tree four years old that has been headed-in every year. An open tree like this that has been regularly headed-in has many small fruiting branches on the interior limbs.

Photo. Prof. W. H. Chandler, University of Missouri.

which are added arsenate of lead to control the later broods of the codling moth, and the fungus diseases previously mentioned.

544. The Cultivated Stone Fruits include the peach, apricot, nectarine, plum and cherry. The fruits are usually well colored, and highly flavored when ripe. They are firm up to the full ripening period at which time they develop a high content of sugar and become soft. They may be gathered when mature, but before ripening, and transported long distances, especially in refrigerator cars. The ripening process goes on after the fruit is gathered. The stone fruits are usually propagated by budding and the trees set into the orchard at one year from the bud, in rows 12 to 18 feet apart. The young trees are headed back to a short stem 15 to 24 inches from the ground. The annual pruning is not a cutting-out process, as in the pome fruits, but a heading-in of the branches by cutting off their ends. This makes the branches stouter and better able to support the crop of fruits. (See ¶ 188.) The curculio and the brown rot (Fig. 91) are the most generally serious diseases to stone fruits. Spraying with self-boiled, lime-sulfur wash affords protection from the brown rot, and when combined with arsenate of lead, also the curculio.

545. Frost Injury. The stone fruits are subject to winter killing of buds, and even branches in the central and northern states. A few warm days will cause early blooming, with consequent danger of injury by late frost. For this reason the site for peach or plum orchards should be preferably located on ridges or elevated flats with steep slopes into near-by valleys. In such situations the cool air drains off at night, and as a rule trees in such situations are later in flowering than they would be in the valleys, and hence will oftener escape frost injury.

APPENDIX A

BOOKS ON AGRICULTURE

The following books are recommended for use of teachers for reference, and for supplementary reading in school work. The more important ones are starred thus.*

Primarily for Teachers —

- *The Corn Lady, Field. A. Flanagan, Chicago.
- *The Story of the Soil, Hopkins. Gorham Press, Boston
- Report Country Life Commission. Sturgis & Walton, New York.
- The Rural Life Problem, Plunkett. Macmillan Co.
- Farm Boys and Girls, McKeever. Macmillan Co.
- The American Rural School, Foight. Macmillan Co.
- The Story of Cotton. Rand, McNally & Co.

Plants, Crops and Soils —

- *Cereals in America, Hunt. Orange Judd Co., New York.
- Forage and Fiber Crops, Hunt. Orange Judd Co.
- *Principles of Fruit Growing, Bailey. Macmillan Co.
- *Manual of Gardening, Bailey. Macmillan Co.
- *The Book of Alfalfa, Coburn. Orange Judd Co.
- Alfalfa in America, Wing. Sanders Pub. Co., Chicago.
- Practical Botany, Bergen and Caldwell. Ginn & Co.
- *Disease in Plants, Ward. Macmillan Co.
- Principles of Plant Culture, Goff. University Co-op., Madison, Wis.
- *Irrigation and Drainage, King. Macmillan Co.
- Vegetable Gardening, Watts. Orange Judd Co., New York.
- *Soil Fertility and Permanent Agriculture, Hopkins. Ginn & Co.
- First Book of Farming, Goodrich. Doubleday, Page & Co.

Animal Husbandry —

- The Care of Animals, Mayo. Macmillan Co.
- Feeding of Farm Animals, Jordan. Macmillan Co.
- *Types and Breeds of Farm Animals, Plumb.
- *Profitable Feeding, Smith.
- Swine in America, Coburn. Orange Judd Co.
- Principles of Poultry Culture, Robinson. Ginn & Co.

Miscellaneous —

- *Physics of Agriculture, King. F. H. King, Madison, Wis.
- The Young Farmer, Hunt. Orange Judd Co.
- Farm Machinery, Davidson and Chase. Orange Judd Co.
- *Plants and Animals Under Domestication, Darwin. D. Appleton Co., New York.

APPENDIX B

INSECTICIDES AND FUNGICIDES

1. The Governing Principles in the use of insecticides and fungicides were given in Chapters 21, 22 and 23. Below, brief directions for making the most generally used mixtures are given. More detailed information may be secured from your State Agricultural Experiment Station or the U. S. Department of Agriculture, or manufacturers of spraying machinery.

2. **Copper Sulfate Solution.** Soluble copper salts are very poisonous to fungi and algae in even very dilute solution. They are only moderately so to higher plants and animals. There is no case on record of anyone becoming poisoned from eating fruit sprayed with copper salts. Because of its cheapness copper sulfate is most generally used for fungicide solutions. When used to spray plants in leaf it is necessary to add lime to neutralize the scorching acid effect on the leaves and to give the mixture adhesive quality. For spraying dormant trees it is used without the lime, as follows:

Copper sulfate, (Blue Stone).....	3 pounds
Water.....	50 gallons

3. **Bordeaux Mixture** is the most generally used fungicide. The standard formula is 4 pounds of copper sulfate, 4 pounds of fresh lime and 50 gallons of water, and is usually referred to as the

4-4-50 formula. The proportions are varied for special purposes, as 3-9-50 for peach trees which have delicate foliage.

In preparing, use two half-barrels, as shown in Fig. 230. The copper sulfate should be pulverized and put into a coarse burlap sack and suspended in water until dissolved. By using warm



Fig. 230. Making Bordeaux mixture.

water the dissolving process may be hastened. Use wooden tubs for the copper sulfate. The fresh lime should be mixed with water in another vessel, using only a small amount of water at first, adding as the slacking progresses. Add water till a thin batter is formed. Stir freely to destroy even small lumps. Add more water and strain through a burlap sack. Dilute the milk of lime to about 25 gallons, and likewise the copper sulfate. Mix by pouring in equal quantities of each into a third vessel, as suggested by Fig. 230.

Success in preparing Bordeaux mixture of uniform quality, color, and consistency will depend on the materials and the manner of mixing. When properly prepared, it has a sky-blue color. If the lime is not fresh, a greenish color sometimes results, which indicates that more lime is needed. It is advisable to have an excess of lime. When peaches and other plants with delicate foliage are to be sprayed, three times as much lime as copper sulfate is used.

4. Ammoniacal Copper Carbonate Solution is used sometimes in spraying ornamentals or for the last spraying of grapes, when the Bordeaux mixture would be objectionable.

Copper carbonate.....	5 ounces
Strong ammonia (26° Baume').....	2 to 3 pints
Water.....	50 gallons

5. Insecticides With Bordeaux Mixture. It is often desirable to combine an insecticide with a fungicide in order to obviate the necessity of making two sprayings. This is often done when internal poisons, like arsenate of lead, Paris Green, London Purple, are used. They may be added to the Bordeaux mixture at the rate indicated by the formula usual for insecticides.

6. Lime and Sulfur Preparations are much used to destroy scale insects. They act as a mild fungicide also. The preparations in common use vary as to the proportions of lime and sulfur.

7. Fire-Boiled Lime-Sulfur Wash. Use the following:

Fresh lime.....	15 to 30 pounds
Flowers of sulfur.....	15 pounds
Water to make.....	50 gallons

When the lime is perfectly fresh, the smaller quantity named above will answer. To make the preparation, proceed as follows: Slake the lime with hot water, adding the water slowly until about ten gallons are used. Then add the sifted sulfur and stir until thoroughly mixed. Boil this mixture for from forty-five to sixty

minutes to thoroughly dissolve the sulfur. The sulfur dissolves most easily in a thin, milky solution of lime, and, for this reason, no more water is used in dissolving the sulfur than is necessary to keep the mixture from becoming pasty. When the sulfur is thoroughly dissolved, pass the solution through a strainer and dilute to the desired concentration with hot water. The mixture should be prepared just as needed, and applied while still warm.

8. Self-Boiled Lime-Sulfur Wash is a combination of lime and sulfur boiled only with the heat of the slaking lime. It is sometimes used for spraying peaches as a substitute for Bordeaux mixture when the latter is injurious to the foliage.

Sulfur, free from lumps.....	10 pounds
Fresh lime.....	10 pounds
Water.....	50 gallons

Place the lime in a barrel, spread to keep the sulfur off the bottom of the barrel and add about a gallon of water to start it to slaking. Now add the sulfur and enough water to make the mixture into a paste, about 3 to 4 gallons. Stir vigorously to prevent caking at the bottom. After the violent boiling due to the slaking lime is over, dilute freely to stop the boiling; strain to remove the coarse particles of lime and add the full quantity of water.

9. Arsenical Insecticides. Formerly London Purple and Paris Green were much used for insecticides. These substances are heavy and are somewhat troublesome to keep mixed with the water, and are likely to injure the foliage. In recent years arsenate of lead has come into general use and has largely replaced other arsenic compounds used for insecticides. It stays in suspension longer and adheres better and is less likely to injure the foliage.

Arsenate of lead.....	1 to 3 pounds
Water (or Bordeaux or lime-sulfur).....	50 gallons

Arsenate of lead may be purchased in the form of dry powder or as a putty-like paste. As there are many grades of arsenate of lead on the market some caution should be exercised in making purchases.

10. Kerosene Preparations. Kerosene oil is an external irritant and is very effective in killing insects. It can not be applied to plants, however, in its crude form, without producing serious

injury. Resort is had, therefore, to various substances to dilute and carry the oil, such as soap-suds, milk, milk of lime, or even water alone, when mixed with the water in forming the spray. Kerosene preparations should be applied to plants with great caution. They are very efficient in fighting certain injurious insects, but if not properly applied, serious injury to the plant may result.



Fig. 231. Hand-bucket spray pump. A longer hose than that shown is needed for convenient using.

11. Kerosene Emulsion. Used for scale and other sucking insects. Dissolve $\frac{1}{2}$ -pound of hard soap in one gallon of boiling water. Then add two gallons of kerosene oil to the water and thoroughly mix by pumping the entire mixture through a bucket sprayer until an emulsion is formed. (Fig. 231.) The bulk of the mixture will increase about one half in the process and assume the consistency of cream. Now dilute to from twenty to thirty gallons as desired.

12. Soluble or Miscible Oils. In recent years preparations of emulsions of the common oils have come into use. They are probably not so good as lime-sulfur preparations but may be applied with less annoyance when only a few plants are to be sprayed. They are usually sold under proprietary names. All that is necessary is to dilute with water and spray as directed.

13. Dust Applications of Insecticides have not been so uniformly satisfactory as the liquid applications and are little used.

14. Spraying Domestic Animals with poisons is sometimes recommended to kill insects, ticks, and other parasites. Various preparations of oils and arsenical preparations are used. London Purple, dusted on the perches, nests, and bodies of poultry, is a very satisfactory way to destroy mites on poultry. If applied regularly, it becomes a preventive.

APPENDIX C

COMPOSITION OF AMERICAN FEEDING STUFFS

	Pounds per hundred					
	Water	Ash	Protein	Fiber	Nitrogen-free extract	Fat
GREEN FEEDS.						
Corn fodder, whole plant	73.4	1.5	2.0	6.7	15.5	0.9
Kaffir corn fodder	73.0	2.0	2.3	6.9	15.1	0.7
Sorghum fodder	69.4	1.8	1.6	8.8	16.8	1.6
Kentucky Blue grass	65.1	2.8	4.1	9.1	17.6	1.3
Johnson grass						
Alfalfa	71.8	2.7	4.8	7.4	12.3	1.0
Cowpea	83.6	1.7	2.4	4.8	7.1	0.4
Peanut vines						
DRY HAY AND FODDERS.						
Corn fodder, entire plant	42.2	2.7	4.5	14.3	34.7	1.6
Corn fodder, leaves only	30.0	5.5	6.0	21.4	35.7	1.4
Corn husks from ears	50.9	1.8	2.5	15.8	28.3	0.7
Kaffir corn stover	19.2	8.0	4.8	26.8	30.6	1.6
Hay from						
Oats	16.0	6.1	7.4	27.2	40.6	2.7
Timothy	13.2	4.4	5.9	29.0	45.0	2.5
Prairie grass	7.7	6.4	3.8	34.8	45.7	1.5
Johnson grass	9.9	5.7	12.8	29.1	39.8	2.7
Millet	8.8	10.1	11.1	32.1	34.8	2.9
Mixed grasses	15.3	5.5	7.4	27.2	42.1	2.5
Red clover	20.8	6.6	12.4	21.9	33.8	4.5
Alfalfa, minimum	4.6	3.1	10.2	14.0	35.1	1.1
Alfalfa, maximum	16.0	10.4	20.3	33.0	53.6	3.8
Alfalfa, average	8.4	7.4	14.3	25.0	42.7	2.2
Cowpea	10.7	7.5	16.6	20.1	42.2	2.9
Peanut vines, without nuts ...	7.6	10.8	10.7	23.6	42.7	4.6
Oat straw	9.2	5.1	4.0	37.0	42.4	2.3
Wheat straw	9.6	4.2	3.4	38.1	43.4	1.8
ROOTS AND TUBERS.						
Sweet Potatoes	71.1	1.0	1.5	1.3	24.7	0.4
Irish potatoes	78.9	1.0	2.1	0.6	17.3	0.1
Sugar beets	86.7	0.8	1.5	0.9	9.9	0.1
Turnips	90.6	0.8	1.3	1.2	5.9	0.2
Carrots	88.6	1.0	1.1	1.3	7.6	0.4

APPENDIX C, continued

COMPOSITION OF AMERICAN FEEDING STUFFS, continued

	Pounds per hundred					
	Water	Ash	Protein	Fiber	Nitrogen-free extract	Fat
GRAINS AND SEEDS.						
Corn, minimum	6.2	1.0	7.5	0.9	65.9	3.1
Corn, maximum	19.4	2.6	11.8	4.8	75.7	7.5
Corn, average	10.6	1.5	10.3	2.2	70.4	5.0
Kaffir corn	12.5	1.3	10.9	1.9	70.5	2.9
Barley	10.9	2.4	12.4	2.7	69.8	1.8
Oats	11.0	3.0	11.8	9.5	59.7	5.0
Sunflower seed	8.6	2.6	16.3	29.9	21.4	21.2
Cotton-seed, whole	5.8	2.9	14.5	10.9	17.3	15.3
Cotton seed, hulls	11.1	2.8	4.2	46.3	33.4	2.2
Cotton-seed meal	8.2	7.8	42.3	5.6	23.6	13.1
Peanut hulls	9.0	3.4	6.6	64.3	15.1	1.6
Peanut, kernel only	7.5	2.4	27.9	7.0	15.6	39.6
Cowpeas	11.9	3.4	23.5	3.8	55.7	1.7
BY-PRODUCTS OF MILLS.						
Corncob	10.7	1.4*	2.4	30.1	54.9	0.5
Germ from corn	10.7	4.0	9.8	4.1	64.0	7.4
Germ meal from corn	8.1	1.3	11.1	9.9	62.5	7.1
Wheat bran	11.9	5.8	15.4	9.0	53.9	4.0
Wheat middlings	12.1	3.3	15.6	4.6	60.4	4.0
Wheat shorts	11.8	4.6	14.9	7.4	56.8	4.5
Rice bran	9.7	10.0	12.1	49.5	49.9	8.8
DAIRY PRODUCTS.						
Whole milk	87.2	0.7	3.6	...	4.9	3.7
Skim milk, gravity creaming ...	99.4	0.7	3.3	....	4.7	0.9
Skim milk, separator	90.6	0.7	3.2	....	5.2	0.3
Buttermilk	91.0	0.7	3.0	....	4.8	0.5
Whey	93.8	0.4	0.6	....	5.1	0.1
BY-PRODUCTS, PACKERY.						
Dried blood	92.0	....	87.0	....	....	....
Meat scraps	78.0	17.39	49.72	....	....	18.51
Tankage	92.0	....	60.0	....	....	8.0

APPENDIX D

PER CENT OF DIGESTIBLE NUTRIENTS IN STOCK FEEDS

	Animal	Digestion coefficients						
		Dry matter	Organic matter	Ash	Protein	Fiber	Nitrogen-free extract	Fat
		%	%	%	%	%	%	%
Timothy, green	Steers	63.5	65.6	32.2	48.1	55.6	65.7	53.1
Timothy, green	Horse	43.5	44.1	34.1	21.2	42.6	47.3	47.3
Timothy, hay, dry .....	.....	53.4	54.5	30.3	45.1	47.1	60.4	51.9
Mixed hay .....	.....	....	....	....	48.0	48.0	57.0	50.0
Oat straw .....	.....	....	....	....	38.-	58.0	53.0	38.0
Oat straw .....	.....	50.3	52.0	....	....	57.6	53.2	38.0
Johnson grass, dry .....	.....	56.5	58.3	30.5	41.4	65.7	56.9	38.4
Corn fodder, leaves .....	.....	59.8	63.6	26.8	48.4	67.5	63.0	59.9
Corn shucks .....	.....	72.0	74.2	16.0	29.5	79.5	75.0	32.5
Alfalfa hay .....	.....	58.9	60.7	39.5	72.0	46.0	69.2	51.0
Corn, unground	Horse	74.4	75.3	26.3	57.8	....	88.2	47.7
Corn meal	Horse	88.4	....	....	75.6	....	95.7	73.1
Corn, unground	Swine	82.5	83.4	....	68.7	38.3	88.8	45.6
Corn, ground	Swine	89.5	91.2	....	86.1	29.4	94.2	81.7
Corn meal	Sheep	89.6	90.7	49.5	76.9	....	95.3	98.1
Corn meal	Cows	84.6	82.8	....	58.3	....	87.1	91.9
Oats, unground	Horse	72.4	74.1	33.1	86.1	31.1	79.4	82.4
Oats, ground	Horse	75.7	77.7	29.2	82.4	14.4	86.3	79.9
Wheat bran	Swine	65.8	....	....	75.1	33.0	65.5	71.8
Wheat bran	Sheep	58.7	61.6	17.3	70.2	16.1	67.2	72.1
Wheat bran	Steers	67.3	68.6	47.1	82.3	25.1	74.6	54.7
Cotton-seed hulls	Cow	35.9	36.2	27.1	24.6	27.4	40.3	80.6
Cotton-seed hulls	Goats	38.6	39.8	20.9	....	45.2	37.4	87.1
Cotton-seed meal	Goat	65.9	69.5	19.8	86.8	46.8	43.8	92.4
Cotton-seed meal	Cow	77.9	80.0	35.0	89.8	....	68.1	89.4
Cotton seed, raw .....	.....	66.1	65.8	43.3	67.8	75.5	49.6	87.1
Cotton seed, roasted .....	.....	55.9	56.8	....	46.9	65.9	51.4	71.7
Potatoes, raw .....	.....	75.7	77.0	....	44.7	....	90.4	13.0
Potatoes, boiled .....	.....	80.1	81.2	....	43.4	....	92.1	....
Sugar beets .....	.....	94.5	98.7	31.9	91.3	100.0	99.7	49.9
Turnips .....	.....	92.8	96.1	58.6	89.7	100.0	96.5	87.5

APPENDIX E

AVERAGE DIGESTIBLE NUTRIENTS AND FERTILIZING CONSTITUENTS IN STOCK FEEDS

	Dry matter in 100 pounds	Digestible nutrients in 100 pounds				Fertilizing consti- tuents in 100 pounds		
		Protein	Carbo- hydrate	Fat	Fuel value	Nitrogen	Phosphoric acid	Potash
GREEN FEEDS.								
Corn fodder, entire plant	20.7	1.10	12.08	0.37	26.076	0.30	0.15	0.30
Kaffir corn fodder....	27.0	0.87	13.80	0.43	29.101			
Sorghum fodder.....	30.6	0.70	17.60	0.20	.....	0.30	0.09	0.25
Red clover	29.2	3.07	14.82	0.69	36.187	0.54	0.15	0.40
Cowpea vines	16.4	1.68	8.08	0.25	19.209	0.27	0.10	0.30
Alfalfa	28.2	3.89	11.20	0.41	29.798			
DRY FODDERS AND HAY								
Corn stover.....	59.5	1.98	32.16	0.57	67.766	1.10	0.29	1.40
Kaffir corn stover....	80.8	1.82	41.42	0.98	84.562			
Sorghum stover .....	....	....	....	....	....	....	....	....
Johnson grass.....	55	3.24	41.31	0.82	47.577	....	....	....
Red clover	84.7	7.38	38.15	1.81	92.324	0.54	0.15	0.40
Cowpea vine hay	89.3	10.79	38.40	1.54	97.865	2.66	0.52	1.47
Alfalfa hay	91.6	10.58	37.33	1.38	94.936			
Peanut vine hay	60.0	6.74	31.94	3.03	80.918	....	....	....
Wheat straw	90.4	0.37	36.30	0.40	69.894	0.60	0.22	0.63
Oat straw	90.8	1.20	38.64	0.76	77.310	0.46	0.28	1.77
Hay, mixed grasses..	87.1	5.90	40.90	1.20	93.925	1.40	0.27	1.55
GRAINS AND SEEDS.								
Corn, whole grain ...	89.1	8.00	65.90	4.60	157.237	1.58	0.57	0.37
Corn meal	89.1							
Kaffir corn.....	87.5	5.78	53.58	1.33	116.022			
Oats.....	89.0	9.25	48.34	4.18	124.757	1.65	0.69	0.48
Wheat, all varieties..	89.5	10.23	69.21	1.68	154.848			
Wheat bran	88.1	12.20	39.20	2.70	111.138	2.67	2.89	1.61
Wheat middlings ...	87.9	12.80	53.00	3.40	136.996	2.63	0.95	0.63
Wheat shorts	88.2	12.22	49.98	3.88	131.855			
Cotton seed.....	89.7	11.08	33.13	18.44	160.047			
Cotton-seed meal....	91.5	38.10	16.00	12.60	152.653	6.90	3.00	1.50
Cotton-seed hulls...	89.5	0.30	32.90	1.70	69.839	0.69	0.25	1.02
ROOT CROPS.								
Irish potatoes.....	21.1	1.36	16.43	.....	33.089	0.24	0.08	0.37
Turnips	9.5	0.81	6.46	0.11	13.986	0.19	0.09	0.34
Carrots	11.4	0.81	7.83	0.22	16.999			
Beets	13.0	1.21	8.84	0.05	18.904			

APPENDIX F

STANDARD FEEDING RATIOS

Approximate requirements of nutrients for a day's feeding per 1,000 pounds live weight

	Dry matter	Digestible nutrients			Fuel value	Nutritive ratio
		Protein	Carbo- hydrate	Fat		
Oxen—	Lbs.	Lbs.	Lbs.	Lbs.	Calories	
At rest in stall	18	0.7	8.0	0.1	16,600	1:11.6
At light work	22	1.4	10.0	0.3	22,500	1:9.3
At heavy work	28	2.8	13.0	0.8	32,755	1:5.0
Dairy cattle, in milk—						
Giving 11 pounds milk a day	25	1.6	10.0	0.3	22,850	1:6.8
Giving 16.5 pounds milk a day	27	2.0	11.0	0.4	25,850	1:5.4
Giving 22 pounds milk a day	29	2.5	13.0	0.5	30,950	1:5.6
Giving 27.5 pounds milk a day	32	3.3	13.0	0.8	33,700	1:4.5
Cattle, growing age—						
About 150 lbs., 2 to 3 months ...	23	4.0	13.0	2.0	40,050	1:3.4
About 300 lbs., 3 to 6 months ...	24	3.0	12.0	1.0	33,600	1:4.7
About 500 lbs., 6 to 12 months ...	27	2.0	12.5	0.5	29,100	1:6.8
About 700 lbs., 12 to 18 months ..	26	1.8	12.5	0.4	28,300	1:7.5
About 900 lbs., 18 to 24 months ..	26	1.5	12.0	0.3	26,350	1:8.4
Sheep—						
Heavy-fleeced breeds	23	1.5	12.0	0.3	26,400	1:8.5
Ewes, with lambs	25	2.9	15.0	0.5	35,400	1:5.5
Growing, wool breeds—						
60 to 75 lbs., 4 to 8 months	25	3.2	14.0	0.7	35,500	1:4.9
80 to 90 lbs., 8 to 15 months ...	23	2.0	11.3	0.4	26,000	1:6.1
Growing, mutton breeds—						
60 to 80 lbs., 4 to 8 months	26	4.0	15.0	0.7	38,000	1:4.1
100 to 150 lbs., 8 to 15 months .	23	2.2	13.0	0.5	30,000	1:6.4
Swine—						
Growing, breeding stock—						
50 to 100 lbs., 2 to 5 months ...	40	6.5	25.5	0.9	60,000	1:4.0
120 to 200 lbs., 5 to 8 months ..	30	3.8	20.0	0.4	45,000	1:5.5
200 to 250 lbs., 8 to 12 months .	26	3.0	17.0	0.2	35,000	1:5.8
Growing, fattening—						
About 50 lbs., 2 to 3 months ...	44	7.6	28.0	1.0	70,000	1:3.7
About 100 lbs., 3 to 5 months ..	35	5.0	23.0	0.8	55,650	1:4.7
About 150 lbs., 5 to 6 months ..	33	4.3	22.3	0.6	52,000	1:5.4
About 200 lbs., 6 to 8 months ...	30	3.6	20.5	0.4	45,500	1:5.9
About 275 lbs., 9 to 12 months .	26	3.0	18.3	0.3	40,900	1:6.3

APPENDIX G

STANDARD FEEDING RATIONS

Approximate requirements of nutrients per day per head

	Age	Average live weight per head	Digestible nutrients			Fuel value	Nutritive ratio
			Protein	Carbo-hydrate	Fat		
	Months	Lbs.	Lbs.	Lbs.	Lbs.	Calories	
Growing cattle	2-3	150	0.60	2.10	0.300	6,288	1:4.6
	3-6	300	1.00	4.10	0.300	10,752	1:4.7
	6-12	500	1.30	6.80	0.300	16,332	1:5.3
	12-18	700	1.40	9.10	0.280	30,712	1:6.8
	18-24	850	1.40	10.30	0.260	22,859	1:7.7
Growing sheep	5-6	56	0.18	0.87	0.045	2,143	1:5.4
	6-8	67	0.17	0.85	0.040	2,066	1:5.4
	8-11	75	0.16	0.85	0.037	2,035	1:6.0
	11-15	82	0.14	0.89	.032	2,050	1:7.0
	15-20	85	0.12	0.88	0.025	1,956	1:8.0
Growing fat swine	2-3	50	0.38	1.50		3,497	1:4.0
	3-5	100	0.50	2.50		5,580	1:5.0
	5-6	125	0.54	2.96		6,510	1:5.5
	6-8	170	0.58	3.47		7,533	1:6.0
	8-12	250	0.62	4.05		8,686	1:6.3



Fig. 232. Mean annual rainfall of the United States. (U. S. Weather Bureau.)

APPENDIX H

ANNUAL RAINFALL IN THE UNITED STATES

Precipitation (rain, snow, etc.) for the years given

STATIONS	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	Average
Ft. Smith, Ark.	51.1	40.2	39.0	22.7	35.1	35.4	31.4	42.5	42.5	35.6	37.5
Little Rock, Ark.	49.5	41.3	43.5	36.8	54.0	40.5	40.1	56.0	47.0	50.5	45.9
Texarkana, Ark.	44.1	30.0	....	33.1	....	....	44.5	76.7	....	....	45.7
Austin, Tex.	28.1	31.9	54.0	19.5	32.8	36.2	37.9	35.8	21.5	30.0	32.8
Beaumont, Tex. ....	....	....	....	37.9	63.6	....	40.3	62.7	39.4	56.7	50.1
Amarillo, Tex.	22.5	27.4	24.4	24.4	23.1	20.3	21.3	32.3	24.9	18.6	23.9
El Paso, Tex.	6.1	7.3	7.9	8.7	10.1	11.6	11.3	17.8	15.0	8.4	10.2
Sherman, Tex. ....	....	....	....	....	46.8	32.6	28.0	58.9	47.8	....	42.8
Santa Fe, N. Mex. ...	12.9	10.0	15.9	17.4	13.3	9.8	14.2	17.2	16.6	15.1	14.2
Denver, Colo.	13.0	9.3	15.3	9.1	13.3	9.5	14.0	17.7	16.8	11.8	13.0
Garden City, Kans. ...	28.7	20.6	19.3	18.3	19.6	20.6	21.0	21.0	27.1	20.9	21.7
Kansas City, Mo.	50.2	32.5	35.8	24.7	40.5	39.2	47.7	42.5	32.8	37.6	38.3
St. Louis, Mo.	49.2	34.6	29.5	24.8	38.4	33.8	33.7	38.5	35.5	41.4	35.9
Vicksburg, Miss.	55.6	47.2	53.3	57.5	47.3	38.0	41.6	60.5	51.7	51.6	50.4
New Orleans, La.	49.0	31.0	56.3	57.7	41.6	57.2	43.7	80.0	41.6	66.3	52.4
Memphis, Tenn.	48.6	39.0	47.4	34.6	50.3	36.1	42.5	55.8	54.3	41.5	45.0
Birmingham, Ala. ...	46.5	48.5	76.2	61.6	54.4	50.5	34.3	50.8	64.7	54.6	54.2
Atlanta, Ga.	50.5	42.4	58.8	59.7	43.9	48.6	33.1	42.5	53.6	39.4	47.3
Richmond, Va.	41.6	43.3	37.7	42.0	49.3	47.4	37.8	38.4	46.8	48.5	43.3
Washington, D. C. ...	37.7	44.0	41.2	41.7	46.6	43.5	40.8	50.6	52.9	44.6	44.4
New York, N. Y.	45.1	42.0	41.8	47.0	47.0	48.6	41.5	44.5	41.8	45.2	44.4
Boston, Mass.	49.8	34.7	44.0	48.7	33.9	41.9	39.6	32.1	40.7	37.5	40.3
Chicago, Ill.	33.7	26.4	28.6	24.5	37.5	28.0	26.1	35.3	30.8	35.1	30.6
Fargo, N. D.	16.3	21.2	25.5	25.7	23.2	21.9	20.2	....	17.7	....	22.6
Helena, Mont.	17.4	11.8	11.6	14.7	10.0	11.3	7.5	10.1	14.2	12.7	12.1
Seattle, Wash.	29.3	37.1	36.3	30.1	45.8	34.5	37.7	34.3	36.6	29.1	35.1
Spokane, Wash.	13.1	20.1	18.7	16.0	19.2	16.5	13.9	16.7	17.6	17.6	16.9
San Bernardino, Cal. .	5.7	10.1	12.5	12.0	13.3	14.1	10.2	22.9	25.8	17.4	14.4
San Francisco, Cal. . .	9.3	23.2	15.3	19.7	19.2	18.3	24.7	16.2	26.3	22.5	19.4
Salt Lake City, Utah .	16.1	17.5	11.5	16.0	11.4	14.6	16.3	14.2	21.3	19.2	15.8
Ardmore, Okla.	33.7	36.2	36.1	23.4	47.6	26.8	24.1	40.1	43.4	38.9	36.4
Durant, Okla. ....	....	....	....	....	46.4	43.8	32.5	51.8	43.5	....	43.6
Ft. Sill, Okla.	37.3	46.5	36.5	16.1	46.8	18.7	30.3	50.1	38.8	....	31.6
Mangum, Okla.	30.9	....	....	....	....	19.3	20.1	....	39.9	....	24.4
McAlester, Okla.	47.3	45.4	33.7	31.6	53.2	46.1	39.5	48.8	38.9	....	42.7

APPENDIX I

GLOSSARY

Abdomen. That part of an animal's body containing the digestive organs; the part of an insect lying behind the thorax.

Acid. A sour substance, such as vinegar, lemon juice, etc.

Æsthetic. Appealing to the faculties of taste, as in form, color, etc.

Agriculture. Farming.

Agronomy. Pertaining to or about field crops.

Air-dry. Dried in air at ordinary temperatures.

Albumin. A substance found in plants and animals, rich in nitrogen.
The white of an egg is a good example.

Alga. A green plant of simple structure, such as pond scum.

Ameliorate. To improve; make better.

Amendment. Substances which improve the productiveness of soils without being used directly as plant foods.

Ammonia. A compound containing nitrogen readily converted into plant food.

Animal Husbandry. Raising and caring for animals.

Annual. A plant that bears seed during the first year of its existence and then dies.

Anther. The part of a stamen that bears the pollen.

Antiseptic. Substances which kill germs or microbes.

Art. The skillful and systematic arrangement or adaptation of means for the attainment of some end.

Ash. The mineral substance left when plant or animal substances are burned.

Assimilation. The absorption of digested nutrients into the body substance. Also sometimes used as synonymous with carbon assimilation.

Atmospheric Nitrogen. Free nitrogen of the air.

Available. Said of fertilizing mineral nutrients in the soil when they are in a condition to be absorbed and used by plants.

Axils. Angle above the junction of a leaf-stalk with the parent stem.

Babcock Tester. Instrument used for determining the amount of butter-fat in milk.

Bacteria. A name applied to a class of very small parasitic plants. There are many kinds, most of which are beneficial to man. Some species are the cause of disease in man and the higher animals or plants.

Biennial. A plant that grows during the first year, and forms seeds, and dies the year following, such as turnips, beets.

Bioplasm. The living substance of cells. See Protoplasm.

Blight. A diseased condition of plants in which the entire plant or some part withers and dries up.

Bordeaux Mixture. A mixture of lime and copper sulphate (blue-stone), used to prevent fungus diseases on plants. It takes its name from Bordeaux, France, where it was first used.

Botany. The science that deals with plants.

Breeding. Plant-breeding; animal-breeding. The practice of selecting out the best individuals for propagation.

Bud (noun). An undeveloped branch.

Bud (verb). To insert a bud, as in the practice of budding.

Bud Variation. Where a bud produces a branch that possesses characteristics different from the parent plant. New forms originating in this way are called sports.

Bulb. A stem with thickened leaves overlapping one another, as in the onion, Easter lily, etc.

Calcareous. Limy, or having the properties of lime.

Calcium. A chemical element giving limestone its distinctive properties.

Callus. The growth of extra tissue over cut or wounded places on plants.

Calyx. The outermost circle of leaves in a flower.

Cambium. The growing layer of cells lying between the bark and the wood.

Cannon. The shank bone above the fetlock in the fore and hind legs of the horse.

Capillarity. The phenomenon exhibited by the rise of liquids in small or hair-like tubes.

Carbon. The principal chemical element in plants. Charcoal and graphite are forms of carbon.

Carbon Assimilation. The process carried on in the cells of green plants in assimilating the carbon of the carbon dioxide of the air.

Carbon Dioxide. A gas formed whenever substances containing carbon are burned.

Carbon Bisulphide. A chemical compound of carbon and sulphur.

A heavy inflammable liquid used to kill insects in stored grain.

Carbohydrate. Compound of carbon with the elements oxygen and hydrogen in the same proportion that they occur in water. Examples are sugar, starch, wood fiber, etc. They form the largest part of plant substance.

Carnivorous. Feeding on flesh.

Casein. Milk curd, the most important albuminoid in milk and cheese.

Catch Crop. A crop grown during an interval between the harvest of regular crops.

Cellulose. The principal carbohydrate in wood fibers, such as cotton, flax, wood pulp.

Cereal. The name given to the grasses cultivated for their grain, as corn, wheat, kaffir corn.

Chemistry. The science that deals with the properties of the elements and their compounds.

Chlorophyll. The green coloring-matter to which plants owe their characteristic color.

Cion. See *Scion*.

Climatology. The knowledge and science of weather. It includes the science of weather (local climate) and meteorology.

Coming True. Reproducing the variety characters.

Compost. Rotted organic matter, plant or animal.

Concentrates. A term used to designate feeding substances that are almost wholly digestible, as corn, bran, mill products.

Contagious. A disease is said to be contagious when it may be transmitted from one individual to another.

Corolla. The second circle of leaf-like parts of a flower. The corolla is usually colored.

Cotyledons. The primary or seed-leaves of an embryo plant.

Cover Crop. A catch-crop designed to cover the ground during the fall, winter or spring to prevent washing.

Cross. The individual resulting from breeding two varieties together.

Cross-Pollination. The pollination of a flower by pollen from another plant.

Croup (crop). The top of the hips.

Cutting. A part of a stem or root put into the soil or other medium with the intention that it shall grow and make another plant.

Dependent Plants. Plants that do not have the power of making their own food products; i. e., incapable of carbon assimilation.

Digestion. The process of converting the insoluble substances of foods into soluble materials, preparatory to absorption into the blood.

Drainage. The process by which surplus water is removed from the soil, either by ditches, terraces or tiles.

Ecology. The science which treats of the inter-relationships between animals and plants, and their environments. The study of the modes and conditions of life of plants and animals,—a very important phase of agricultural science.

Element. An original form of matter. An ultimate form of matter which can not be further split up by any known means.

Emulsion. A more or less permanent and complete mixture of oils or fats and water. Fresh milk is an excellent illustration.

Endosperm. Reserve food in seeds stored outside of the embryo.

Energy. Power; force. Every movement of, or change of body, expends energy. The energy of sunlight may be expressed in heat, or other form of energy.

Ensilage. See *Silage*.

Entomology. Science of insects.

Erosion. Wearing away. Denudation, as of rocks or soils.

Ether Extract. A term used in feed analyses to describe the substances removed by ether—usually oils.

Evolution. The doctrine that present forms of plants and animals are descended from previous forms. A theory of the origin of forms of living organisms.

Farming. The practice of raising crops and animals.

Farmstead. A farm home or establishment.

Fecundation. The union of male and female cells.

Fermentation. A chemical change produced by bacteria, yeast, etc. Example, souring of milk. The decay of any organic substance is due to some form of fermentation.

Fertilization. Used in the same sense as fecundation. Also used to designate the act of adding fertilizers.

Fertilizer. A substance added to the soil to improve its productiveness, as compost. Some fertilizers are known as amendments, which see.

Fetlock. The long-haired cushion on the back side of a horse's leg, just above the hoof.

Fiber. Any fine thread-like substance, as the wood fibers of stems, cotton fiber, etc.

Fibro-vascular Bundle. The bundles of wood fibers and water-conducting vessels in the stems and leaves of plants.

Flocculate. To make granular by the union of fine particles into aggregates.

Floral Envelope. The collective term for the calyx and corolla.

Fodder. Any coarse dry food for animals.

Forage. Plants fed to animals in their natural condition; or merely dried, i. e., without preparation.

Formalin. A solution in water of the gas known as formaldehyde. It is used to destroy bacteria, fungi, etc.

Function. The particular use of any organ or part.

Fungicide. Substances used to kill fungi, as compounds of copper.

Geology. The science that deals with the formation and properties of the earth.

Germ. See Microbe; bacteria. Also applied to the embryo of seeds, as in corn.

Germinate. To sprout; to grow from a seed or spore.

Girdle. To make a cut or groove around a tree or branch.

Glucose. A kind of sugar, very common in plants. The sugar from grapes is glucose, but the sugar from cane and beets is not. Glucose is formed from starch in the manufacture of syrups.

Gluten. A form of protein found in plants.

Grafting. The practice of inserting a cion into a plant or root that it may grow.

Growth. The increase in size or substance of a plant or animal.

Gypsum. Native form of Plaster of Paris; sulphate of lime.

Herbivorous. Feeding on plants.

Heredity. The phenomenon noted in the resemblance of offspring to parents.

Hibernating. Passing the winter or dormant season in an inactive or torpid state in confined quarters, said of animals.

Hock. The joint in the hind legs of quadrupeds corresponding to the heel of man.

Horticulture. Pertaining to the growing of fruits, vegetables, flowers, and other ornamental plants.

Host. The plant or animal upon which a fungus or insect lives.

Humus (or humous). Decayed or rotten remains of plants and animals found in the soil.

Husbandry. Farming.

Hybrid. The progeny resulting from the crossing of two kinds of plants or animals, either varieties or species. A synonym of cross.

Hydrogen. A chemical element. It is present in water and all living substances.

Hygroscopic. Holding moisture as a film on the surface.

Hypha (plural, hyphæ). The separate threads of the plant body of fungi.

Inoculate. To infect with a disease.

Inorganic. Matter which has not been elaborated into plant or animal substance.

Insectivorous. Eating insects.

Insecticide. A poison used to kill insects.

Internode. The space between two nodes of a stem.

Inter-tillage. Tillage between plants.

Kainit. A salt of potash used in making fertilizers.

Kernel. A single seed, as a grain of corn, wheat, etc.

Kerosene Emulsion. See Appendix B.

Larva (plural, larvæ). The worm-like stage in the development of insects.

Layer. A part of a plant that has been bent down and covered with soil to stimulate the formation of roots. After the roots are formed, it is separated from the parent plant.

Legume. A plant belonging to the same family of plants as the pea, bean, alfalfa, clovers, etc.

Lichen. A kind of fungus plant that grows associated with algæ. Very common on stones and bark of trees

Loam. An earthy mixture of sand and clay, with some organic matter.

Magnesia. A substance containing the chemical element magnesium. It is similar to lime.

Microbe. A general term applied to all plants or animals that are so small that they may be seen only by aid of the microscope.

Mildew. A cobwebby fungus on the surface of diseased or decaying things.

Mold, or Mould. Used in the same way as mildew. Mold occurs only on dead substances. Also a soil with much humus.

Mulch. A loose covering of straw, leaves, or soil, to retard evaporation from the soil.

Nitrate. A compound having nitrogen trioxide (NO_3) combined with a basic mineral substance; a salt of nitric acid, as Sodium nitrate.

Nitrification. The changing of nitrogen into nitrates.

Nitrite. A compound in which nitrogen dioxide (NO_2) is combined with a base.

Nitrogen. A gaseous chemical element composing 79 per cent of the air. It forms a constituent of the more expensive mineral plant-foods. A constituent of ammonia, albumen, proteids and all living substances.

Node. The place on a stem where the leaves and branches originate.

Nutrient. A substance which serves as a food.

Organic. Of or belonging to living things. Organic matter has been formed from simple chemical compounds and exists in nature only as formed by animals or plants.

Osmosis. The movement of a liquid through a membrane.

Ovary. The part of the pistil that bears the seeds.

Ovule. The parts inside of the ovary that grow into seeds.

Ornithology. Science of birds.

Oxygen. A gaseous element composing about one-fifth of the air.

Oxidation. Combining with oxygen, as in the rusting of iron, burning of wood.

Parasite. Dependent plants or animals drawing their food from other living plants or animals. Compare with Saprophyte.

Pedigree. A record of one's ancestors.

Perennial. Plants that live from year to year, as trees.

Petal. Parts of the corolla of flowers.

Phloem. That part of a stem through which the reserve food moves. In plants with netted veined leaves it is just outside of the cambium.

Phosphate. A salt of phosphoric acid. The bones of animals and the shells of oysters are composed of phosphates.

Photosynthesis. Same as Carbon Assimilation.

Physiology. The science that treats of the life processes. It treats of organs and their uses.

Pistil. The part of a flower containing the embryo seeds.

Plumule. The shoot end of an embryo plant.

Pollination. The act of carrying pollen from anther to stigma. It is usually done by the wind or insects.

Pollen. The powdery mass borne by anthers. It is necessary for the formation of seeds.

Potash. A substance containing potassium.

Predaceous. Living by preying, or pillaging. Said of insects that attack and destroy other kinds.

Protoplasm. The living substance. "The physical basis of life."

Proteids. Organic substances rich in nitrogen.

Ration. A daily allowance of food for an animal.

Rotation (of crops). A systematic order of succession of crops on the same land.

Roughage. Dry, coarse fodders.

Sap. The watery solutions in plants.

Saprophyte. Living on dead organic matter.

Scion. A shoot, sprout or branch taken to graft onto another plant.

Science. "Systematized common sense." Knowledge gained and verified by exact observation and correct thinking. KNOWLEDGE deals with simple facts, without reference to inter-relations. ART refers to something to be done. SCIENCE to something to be known and understood.

Sepals. The segments of the calyx.

Silage. Green feed cut up and preserved without loss of succulence.

Silo. A place for keeping silage.

Smut. A term to designate the fungi that produce the blasting of the fruits and leaves of plants, as oat smut.

Soil. That part of the earth's crust permeated by the roots of plants.

Soiling. The practice of feeding green plants in the stables.

Spiracle. Breathing pores of an insect's body.

Spore. The one-celled reproductive body of the lower plants.

Sport. A marked variation from the parents that appears suddenly.

Stamen. The part of a flower bearing the anthers with pollen.

Starch. A carbohydrate found in plants.

Sterilize. To destroy all the germs or spores in or on anything.

Sterile Plants. Plants that do not set seed.

Stigma. The part of a pistil that receives the pollen.

Stover. Dry stalks of corn from which the ears have been harvested.

Stoma (plural, stomata). The minute openings in the epidermis of leaves.

Subsoil. The layer of soil below the surface layer of cultivated soils.

Superphosphate. Phosphates that have been treated with sulphuric acid to render the phosphates soluble.

Thorax. The middle part of an insect's body.

Tillage. The act of preparing the ground to receive the seed and the cultivation of the plants.

Tuber. A thickened underground stem, as an Irish potato.

Tubercle. A small wart-like growth on the roots of legumes, caused by the nitrogen-fixing bacteria.

Variety. A kind or sort of plant.

Viable. Capable of germinating. Having life.

Vigor. Referring to the rapidity of growth, without reference to hardiness.

Vital. Of, or pertaining to living things.

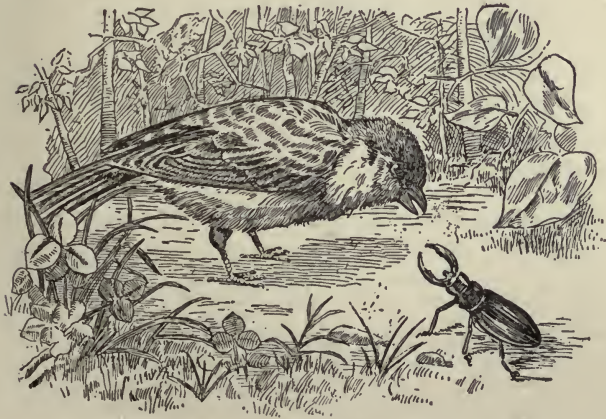
Water-Table. The line of free or gravitational water in the soil.

Weathering. The action of moisture, air, frost, upon rocks, etc.

Weed. A plant where it is not wanted.

Wilt. Used synonymous with blight.

Zoölogy. The science that treats of animals.



“LOOK OUT”

INDEX

Numbers refer to paragraph numbers

- Alfalfa, 432, 433
Apple, 537, 541, 547.
Absorption by Root-Hairs, 22.
Absorption by Soils, 99.
Absorption of Water by Seeds, 24.
Absorption of Water by Soils, 24.
Animal Body, Nutrition of, 322.
Animals, Destroy Insects, 257.
Animal Husbandry, 258, 261.
Animals, Shelter for, 347.
- Babcock Test, 351.
Balanced Rations, Economy of, 335.
Barley 461.
Beet Breeds, 268.
Birds, 249.
Birds, Beneficial, 251.
Birds, Feeding Habits, 254, 255.
Birds, Food of, 250.
Blackberry, 177, 192, 524, 529.
Bordeaux Mixture, Appendix B
Broom Corn, 488.
Butter, Judging, 366.
- Callus, Growth of, 59, 64.
Cambium, 58.
Carbon Assimilation, 47, 48, 50.
Carbon Dioxid, 29.
Capillary Attraction, 71.
Capillary Water, 100.
Catch-Crops, 144.
Caterpillar, 226, 237.
Cells, 13.
Cellular Structure, 13.
Cell-Wall, 8.
Chickens, Breeds, 314.
Chili Saltpeter, 121.
Churning, 365.
Clarification of Milk, 368.
Clay, 89.
Climate and Crops, 415.
Clover, 431, 434.
Coldframes, 36.
Composition of Plants, 45.
Compost, 123.
Compounds of Elements, 40.
Concentrated Foods, 339.
Corn, 439.
Corn Chapter, 462.
Cotton Chapter on, 491
Cover Crops, 107, 144, 431, 434.
Cowpeas, 436.
Creaming, 358.
Cross-Fertilization, 173.
Cultivation, Effect of, 214, 490, 498, 500.
- Cultivation of Soil. (*See* Tilth.)
Currant, 524, 531.
Cuttage, 195.
- Dairy Cows, How Valued, 352.
Dairy Products, Sanitary, 359.
Dairying, 348.
Denitrification, 129.
Dependent Plants, 12.
Dewberry, 531.
Digestible Nutrients, Ratio of, 333.
Digestibility of Feeds, 331.
Disease, Due to Fungi, 215.
Disease, Due to Insects, 146.
Domesticated Plants, 202.
Drainage, 107.
Drainage Waters, Plant Food in, 112.
Drouth, 136.
Drouth Limit, 102.
Drouth-Resistant, 55, 481, 494.
Dry-Land Farming, 97.
- Eggs, Preserving, 313.
Elements, 39.
Elements, Essential, 43, 109, 138.
Elements, in Plants, 41.
Elements, Non-Essential, 44.
Environment, 6.
Epidermis, 47.
- Farm Conditions, Changes in, 398.
Farm Machinery, 391, 394.
Farming, 419.
Feed, Amount of, 338, 479.
Feeding Rations, Standard, Appendixes F and G.
Feeding Stuffs, Composition of, Appendix C.
Feeds, Digestibility of, 331, 487.
Feeds, Nutrients in, 328.
Feeds, Preparation of, 342.
Fertilization of Flowers, 169.
Fertilizer, Quantity of, 111.
Fertilizer, 110.
Fertilizers, Kinds of, 118.
Fertilizing, 132, 430, 503.
Fibro-Vascular Bundles, 57.
Flower-Buds, 156.
Flower-Buds, Formation of, 158, 159.
Flower-Buds, To Distinguish, 157, 538.
Flowers, Names of Parts, 165.
Flowers, Use of Parts, 167.
Forcing, 513.
Forest, Conserving of, 381, 385.
Frost Records, 522.
Fungi, 9.

Fungi, Food of, 8, 9a, 216.
Fungicides, 219. Appendix B.
Fungus Diseases, 215, 451, 533, 543.

Gardens, Individual, 379.
Garden Plans, 379, 517.
Germinating Seeds, 38, 441.
Germination, 15, 20, 27, 34.
Germination, Effect of Air, 29.
Germination, Temperature, 26, 27, 28.
Germination, Time of, 35, 523.
Girdling, Death by, 60, 61.
Goats, 306.
Graftage, 198, 199.
Grains, 438, 442, 486.
Grape, 532.
Grape-Vines, Pruning of, 189.
Green-Manuring, 131, 449.
Green Plants, Food of, 11, 12, 48.
Growth of Flower, 57.
Growth of Fruits, 170.
Growth of Root, 57, 67, 82.
Growth of Stem, 57.
Guano, 122.

Hay, 437.
Hard-Pan, 87.
Harvesting Machinery, 393.
Hellriegel, 80.
Hogs, Types and Breeds, 294.
Home Grounds, 371.
Home-Lot Planning, 372.
Horse, Diagram Showing Points, 292.
Horses, 277.
Hotbeds, 36, 513.
Humus, 91.
Hybridization, 211.
Hygroscopic Water, 100.
Hyphæ, 216.

Incubation, 309.
Insecticides, Appendix B.
Insects, Injurious, 243-248, 507.
Insects, Parasitic, 248.
Insects, Useful, 243-248.

Kerosene Preparations, Appendix B.

Landscape, 369.
Layerage, 194.
Leaf Development, 149.
Leaves, Work of, 46.
Legumes Enrich the Soil, 126, 428.
Legumes, Tubercles of, 125, 429.
Lime in Soils, 139.
Lime-Water, 92.

Machinery, Farm, 394.
Machinery, Influence of, 397.
Manure, Effect of, 115.
Milk, Care in Keeping, 364.
Milk, Changes in, 356.
Milk, Composition of, 354.
Milk, Flow of, 355.
Mineral Food, 112.

Mineral Matter in Soil Waters, 112.
Mulching, 95, 96, 97, 467.
Mulching Strawberries, 527.

Natural Selection, 205.
Natural Science, 3.
Nitrogen, Fixation of, 124, 429.
Nitrogen, Loss from Soil, 130.
Nitrification, 127.
Nitrification, Promoting, 128, 467.
Node, 57, 154.
Nutrients, Digestibility of, 332.
Nutrients in Feeds, 328.
Nutrition of Animal Body, 322.
Nutritive Substances, 323.

Oats, 133a, 213a, 457.
Orchard Fruits, 534.
Orchard Location, 537.
Orchard Spraying, 543, 544.

Palatability of Food, 340.
Parasites, 216.
Pasturage, 346.
Pasteurization, 367.
Pastures, 420, 427.
Peach, 544.
Peanut, 435.
Perennial, 62.
Phloem, 57, 60.
Plant, Soil Relations, 65.
Plant-Food, How Absorbed, 77.
Plant-Food, Kinds of, 8.
Plant-Food, Removed from Soil, 116.
Plant Substances, 37, 39.
Plant Substances, Increase of, 46.
Planting, Depth of, 35.
Planting Seeds, 32, 33.
Plants Dry the Soil, 98.
Plants, Structure of, 13.
Plants, Variation in, 203.
Plow, Webster's, 392.
Plowing, 73, 96, 105, 107, 140.
Plowing, Time of, 445, 448, 501.
Pollination, 171, 440.
Pollination, Importance of, 171, 528.
Potato, 521.
Poultry, 307.
Poultry, Care of Young, 320.
Poultry, Feeding, 311.
Poultry, Improving, 312.
Propagation, Methods of, 190-200.
Propagation of Fungi, 217.
Protoplasm, 8, 14, 42.
Proteids in Plants, 17.
Pruning, 174-178.
Pruning Orchard Trees, 188.
Pruning, Reasons for, 179-185, 544.

Rain, 104, 466.
Rain, Absorption of, 99, 102.
Rainfall, Appendix H.
Raspberry, 529.
Ratios, Application of, 334.
Rations, Kinds of, 336.

- Records of Performance, 256, 474.
 Reserve Food, 17, 37, 38, 160.
 Reserve Food, in Stems, 61, 537.
 Reserve Food, Movement of, 60.
 Reserve Food, Storage of, 64.
 Rice, 459.
 Roads, 399.
 Roads, When to Build, 402.
 Root Growth, 23, 68, 441, 467.
 Root Growth, 77-80; Amount of, 77.
 Root-Hairs, 21, 22, 76.
 Roots, 48, 61.
 Rotation, 142, 449.
 Rotation, Advantages of, 146.
 Roughage, 339.
 Rye, 461.
 Sand, 88.
 Sand Cultures, 109.
 Sanitary Dairy Products, 359.
 Saprophyte, 216.
 School Gardens, 377, 380.
 School Garden, Laying Out, 378.
 Seed Selection, 213, 414, 442.
 Seed-Testing, 31, 443, 475.
 Seedage, 32, 33, 191, 458, 490, 502.
 Seedlings, of Hybrids, 212.
 Seeds, 15.
 Seeds, Germination, 15, 441.
 Seeds, Growth of, 170.
 Seeds of Corn, 18, 469.
 Seeds of Cotton, 19, 505.
 Seeds, Structure of, 16.
 Seeds, Reserve Food, 17.
 Selecting Animals, 263.
 Selecting Seed, 213, 414, 471, 495.
 Self-Fertilization, 172.
 Sheep and Goats, 302.
 Silage, 355, 479.
 Smut of Grain, 222, 451.
 Soil, Change in, 113.
 Soil Classification, 85, 87, 93c.
 Soil, Humus in, 91, 449.
 Soil, Ideal, 69.
 Soil, Improving, 70, 116.
 Soil Management, 71, 84.
 Soil Moisture, 150, 445.
 Soil Mulch, 95.
 Soil Temperatures, 94.
 Soil Tests, 117, 133.
 Soil, Use to Plants, 66.
 Soils, Chemical Analysis of, 117.
 Soils, Exhaustion of, 117.
 Soils Need Fertilizer, 117.
 Soils, Productiveness of, 134.
 Soils, Rise of Water in, 95b.
 Soils, Fertility of, 134.
 Sorghum, 480.
 Split-log Drag, 411.
 Spraying, 231, 543.
 Spore, 216.
 Sprays, How Used, 220.
 Stems, 56. Growth of, 57.
 Stems, Movement of Food in, 60.
 Stems, Movement of Water in, 60.
 Sterile Plants, 162.
 Stock Feeds, Appendix D and E.
 Strawberry, 527.
 Subsoil, 87.
 Temperature of Air, 153.
 Temperature of Soils, 94, 525.
 Terracing, 107.
 Texture of Soils, 74, 132.
 Thinning Fruit, 183.
 Tillage, Depth of, 81, 448, 449.
 Tillage Tools, 392.
 Tilth, 75, 413.
 Tilth, Means of, 73.
 Tilth of Soil, 70.
 Tools, Tillage, 392.
 Transplanting, 201.
 Transportation, 403, 404.
 Tubercles, 125.
 Turkeys, 319.
 Variation in Plants, 203, 214.
 Variation, Fixation of, 204.
 Variations, How Fixed, 204.
 Variations, How Perpetuated, 208.
 Variations Not Permanent, 207.
 Variety Defined, 212.
 Vegetable, Classes of, 514 to 516.
 Water, Absorption by Plants, 66.
 Water-Cultures, 109.
 Water in Irrigation, 103.
 Water, in Plants, 51-53.
 Water, in Soil, 89, 160.
 Water, Favorable to Growth, 102.
 Water, Loss of, by Plants, 47, 54, 465.
 Water, Movement in Plants, 57.
 Water, Needed by Crops, 106.
 Water, Needed by Plants, 47, 51, 465, 457.
 Water, Percolation of, 100.
 Water Storage, 105.
 Water Table, 100.
 Weathering of Soil, 73.
 Weeds, 62, 306, 427.
 Wheat, 133a, 438, 449, 452.
 Windbreaks, 390.
 Woodlot, 388.
 Wool, 303.
 Wounds on Plants, 59.

IC 57228

Edg.
175
1913

361290

Texas

AUG 30 1917

UNIVERSITY OF CALIFORNIA LIBRARY

